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ABSTRACT

Eight general areas were addressed in this conference on Japanese/United States chemical education, including: introductory courses; adequacy of texts, manuals, laboratory workbooks for non-majors; laboratory role in non-major courses; adaptation of such techniques as computers, programmed instruction and videotapes; evaluation and testing instruments; interdisciplinary courses/programs; science/economics/political interface in the instruction of chemistry students; and case studies as an instructional strategy. The bulk of this document includes position papers, full texts of papers, and other supporting materials related to the eight general areas. Fifteen recommendations are suggested, including among others, a continued search in both countries for better courses for non-majors, strengthening U.S. science/mathematics secondary school programs as well as teacher preparation in these areas, emphasizing the role of the laboratory in courses for non-majors, stressing the importance of science processes and contributions of chemistry to non-majors, developing chemistry courses for mathematics-shy students, utilizing a variety of instructional strategies (including computers) and resources, and using interdisciplinary/multidisciplinary approaches. (JN)

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THE IIIRD 1981 JAPAN/USA SEMINAR

FUNDAMENTALS OF CHEMISTRY FOR THE NON-MAJOR IN TERTIARY EDUCATION.

MINIMUM PRINCIPLES FOR THE NON-SCIENCE SPECIALIZING CITIZEN.

SPONSORED BY:

Japan Society for the Promotion of Science

National Science Foundation (Grant S-EDS-0214)

The American Chemical Society, Division of Chemical Education and Education Commission

CO-PRINCIPAL INVESTIGATORS:

Professor Michinori Ōki and Professor Robert C. Brasted

HOST INSTITUTION:

The University of Minnesota, Department of Chemistry

October 31 - November 5, 1981

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INTRODUCTION AND HISTORY.

In 1964 the first Japan/USA Seminar in Education was held in the town of Ōiso near the city of Tokyo. The second in the series was held in 1969 on the campus of the University of California, Lawrence Hall of Science. The basic arrangements for both of these Seminars for the U.S. side were through the National Science Foundation-supported Advisory Council on College Chemistry After nearly a decade, plans for a third program were initiated in part through contacts made by the principal investigator of the current Seminar during a 1977 sabbatical in Japan under the Foreign Scholars Program of the Japan Society for the Promotion of Science. This Seminar had the endorsement not only of the Division of Chemical Education, but also the International Activities Committee of the American Chemical Society. The program came to fruition in November of 1981.

From Japan the participants were selected by a committee designated by the Division of Chemical Education of the Japanese Chemical Society. Professor Michinori Ōki was designated as the principal investigator from that Society.

The members of this group were, in addition to Professor Ōki: Professor Haruo Hosoya, Ochanomizu University; Dean Ayao Kitahara, Tokyo Science University; Professor Kazuo Saito, Tohoku University, Sendai; Professor Tetsuo Shiba, Osaka University; Dean Takashi Shimozawa, Saitama University; Professor Yoshito Takeuchi, College of General Education, University of Tokyo.

From the United States, in addition to Professor Brasted, the participants were: Professor O. T. Benfey, Guilford College; Professor Marjorie Gardner, University of Maryland; Professor Anna Harrison, Mount Holyoke College; Professor John Hill, University of Wisconsin - River Falls; Professor William Kieffer, College of Wooster; Professor Stanley Kirschner, Wayne State University; Professor Joseph Lagowski, University of Texas; Professor W. T. Lippincott, University of Arizona; Professor John Moore, Eastern Michigan University; Professor Richard Ramette, Carleton College; Professor Bassam Shakhashiri, University of Wisconsin - Madison.

PLAN AND DEVELOPMENT OF AGENDA.

The title and the theme of the Seminar were established in part through conferences that were held at the 1979 Pacific Basin Congress. A number of topics, areas of mutual concern, and subjects that might stimulate discussion were developed over a period of approximately a year. These titles, fleshed out with possible variations and suggestions, were circulated to the participants in both countries. An opportunity was afforded for each to indicate those areas of concern which he or she felt sufficiently comfortable and/or knowledgeable in order to prepare brief position papers. In addition to the position papers, which were submitted before the period of the Seminar, the Japanese responded with full texts for their presentations. Certain of the original titles were consolidated and others were deleted to conform to the total period of time available for the Seminar.

Within this text, for each of the titles, initials will on occasion be used parenthetically, referring to a particular contributor. As appendices the full position papers, as well as the full texts, presented by the Japanese will be included. The magnitude of this document is such that only a limited number of copies could be made available. Copy can be obtained on a loan basis by contacting the principal investigator from the United States (RCB). Anyone is at liberty to duplicate this document with the original being returned.

THE PROGRAM.

The first evening's session was devoted to the general description of the procedures, the manner in which the co-chairpersons for each of the day and evening sessions would operate, including what proved to be a satisfactory method of accumulating both written and verbal comments during the Seminar. Each individual had the responsibility of putting into writing a summary of the verbal comments made during or after each of the position paper discussions. These were collected and edited when necessary by the rappateur for each of the sessions. This final report is, then, a digestion and abstraction of these various comments, including a summary of the position and full text papers.

Any reader of this document with even a rudimentary familiarity of the Japanese educational system knows that there are major differences between the United States and Japan, especially in secondary school preparation in science and mathematics. The present higher education plan in Japan has been in effect since World War II. A later section of this report will provide additional information on the system where it pertains particularly to the theme of the Seminar.

Both the hurdles and the consensus that led to the accomplishments of the Seminar are found in the following statement (YT).

> "My impression of the U.S. non-major college or tertiary education is shared, to the best of my knowledge, by all of the Japanese participants. Initially we entered into the Seminar with a somewhat uneasy feeling, knowing that the American and Japanese points of view were slightly out of focus. We initially found it difficult to truly understand your non-science introductory education. It was most fortunate that a site visit was planned to the University of Minnesota since by the first-hand observation we realized far more explicitly the way in which your time, faculties, and facilities, as well as energy in the non-science major course are spent.
>
> In view of the differences between our two secondary education processes, it is doubtful that we should emulate your system; however, this does not reduce our admiration, as well as the appraisal of your efforts. We recognize the variety of teaching methodologies. We are convinced that you are seeking and, in some cases, have found what you believe to be best, and appreciate the fact that you are spending your efforts in the realization of these goals.
>
> One difference in our educational philosophy stands out, and that is a basic question of, "What is a university?" To us, a university is a place where we teach and the students learn *if it is their desire*. It seems that to you in the United States, a university is a place where you teach and the students will learn using a wide range of methods whatsoever they wish. We have, however, a most basic common philosophy in our education, and that is, we both teach chemistry because we love the science."

Although there were no plenary sessions as such, one position paper (OTB) related the eastern and western philosophies in such a way that it made for a proper introduction to the Seminar.

It was emphasized that, whereas we still think of the modern sciences as largely based on mechanics (particles moving in space and time), they have been incorporating also: (a) wave concepts, (b) directional time (entropy, order/disorder, evolution), and (c) the inner complexity of what originally were ultimate units or atoms. These three concepts are related essentially to tradition based on organismic analogies. Their incorporation into modern science has brought in the idea of complementarity. That is to say, the wave-particle dualism, where rational systems cannot combine two concepts. The oriental tradition finds complementarity foreshadowed in the Yin-Yang symbolism. This tradition tends to emphasize organismic rather than mechanical analogies. A modern synthesis would apparently involve all three of the above-mentioned traditions. It is suggested that the U.S. and Japanese chemical educators could jointly explore the feasibility of an entire curriculum which emphasizes the role of these traditions. It is not likely that such could be an introductory course, but could certainly be an enriching course for students at the upper division (senior level in the Japanese system, or junior/senior in the American system). It is quite possible that our entire ecological approach in instruction needs new dimensions that might admit to the inadequacy of analysis only. It is unfortunate that this kind of an approach is not well accepted by the conventional science student. Our engineer, pre-medical student is seeking the quick and well-defined answer, probably one that can be reproduced on an examination without contradiction. It is obvious that the conceiver and designer of the philosophically oriented course such as noted earlier would himself or herself have to be not only well versed in the sciences but in philosophy. Efforts to produce such have involved the joint intellects of two or more disciplines; however, the lifetime of such a course will be a function of the interest and presence of these individuals. Senior staff indulging in this kind of instruction and speculation must be extremely sure of their own knowledge in-depth about the subject. Whatever makes a student think about such material with a depth that defies rote memorization of "facts" has an enriching influence on just the kind of student we are interested in teaching. A possible criticism in the miniscule number of courses approaching the problem from a holistic point of view is that we assume that students think as we do (assuming we are ourselves more analytically inclined), when in fact a student may be more inductive or intuitive than we think, and might benefit more from this holistic approach than from the one we usually use, an analytic one. Reverting to historical times, it is true that philosophy preceded science by many centuries. In more recent times, science and facts come first. The life of the late Nobel laureate, Yukawa, should be brought into focus. His approach is, in a sense, reversed, in that he made his monumental discoveries on the meson while thinking in the absolute sense of a physicist. In his later life he became a very great philosopher, keeping in mind that at this point in his life, he had a tremendous knowledge of scientific facts relating to the nucleus, atoms and matter in general.

Two anecdotes out of many score that could be incorporated to emphasize the need for education of the student described in the title of this Seminar are noted.

The Japanese characters (Kenji) used to describe mercury are identical with those of silver, with the exception of the character for water. Obviously, this is related to the original name of mercury, which is hydroargentum; however, the non-instructed general populus may (and certain ones did) perceive silver and mercury to be the same material. It was conceivable that unwise legislation could arise from a misunderstanding on the part of the lawmakers on nothing more than this interpretation.

In the early years of World War II it was reported (RCB) that all of the sodium chloride in a university stockroom had been impounded by the defense forces on the basis that sodium chloride had "chlorine" in it. It is not difficult to relate or to extrapolate these kinds of judgements to those that relate to "zero pollution". There are times when different value judgements are made by persons of incredibly high scientific capability. The Americans can point to the Three Mile Island incident, in which two well-respected public figures, Linus Pauling and Glenn Seaborg took different points of view on the matter of nuclear energy. Still another value judgement incident is that of a former Director of Environmental Protection Agency. A statement was made to the effect that, "After listening to all of the professional and scientific advice on a matter of the environment and its protection that ultimately I must go to the citizens of this country for their final decision". Such a statement has almost frightening implications when one realizes the very minute fraction of the general public of this country who would be able to make value judgements.

TOPIC 1.

The intensity or rigor of the introductory course for "our audience" was examined. It was evident that a balance between or amongst the qualitative and precise mathematical concepts needs to be established.

An indirect and yet very important issue in the type of course being developed in Japan is not only related to the amount of high school preparation but to the overall capabilities of these students due to the incredibly high competition for seats in the universities and colleges. The number of seats is established by the government, since they are the ones that are paying the cost of education. Such, of course, is not necessarily the case for private universities, since their fees (paid by the Japanese students) will be considerable.

A comparison (or contrast) between our two countries is pertinent in this and other topics in the total Seminar program. In Japan there are 88 National Universities, 33 Prefectural, and 304 Private Institutions. In the latter, the tuition is high, comparable or even exceeding that in our private colleges and universities. With a population about twice that of Japan's the USA counts some 3,000 institutions of higher learning of all types, obviously excluding the "National" since our plan by our our Constitution attempted to place education more in the state than federal domain. The availability of "seats" in Japan is very understandable with these numbers in mind. As a result of high population density in Japan, one person depends upon another and one industry depends upon another. A far higher degree of integration in the educational system is not only possible but necessary in the Japanese than in the American system. The integration in Japan is faciliated by a far greater degree of homogeneity in culture and ethnicity than exists in the USA.

It is possible to weave an entire course with an essentially non-mathematical approach about a study of "the elements" (KS). A number of the participants contributed to the discussion about courses or parts of courses that were devoted to this "elementary" approach. The east-west interface is obvious when one looks to the historical aspects.

The Chinese utilized five elements, including three solids: wood, metals, and earth, which might, in a sense, be a recognition of the differences between bond systems (covalent, metallic, and ionic). Paraselsus, in his classification "tria prima" represents the transition from the Chinese philosophy to the west in the treatment of sulfur, mercury, and salt. It was brought to the attention of the Seminar that a new Australian course utilizes as a basic approach the emphasis on earth, air, fire, and water, representing a further return to the "elements", proceeding to the historical development of the 19th century, and the basic concepts of elements and the combination of atoms to form compounds, and the fulfillment of transmutation with the 20th century ideas of internal structure and nuclear phenomena. An interesting byplay on the development from the time of the alchemists to the present day research philosophy is found in a transition from secrecy to openness. The former was probably partly to safeguard powerful knowledge from misuse and the latter suggests a faith that knowledge by itself enlightens and will lead humanity to higher levels of civilization. The current literature seems to be oriented towards the whole idea of getting back to nature, not only from the above mentioned Australian course and its text "Chemistry, Key to the Earth", but also by a text by one of the Seminar participants (JWM) with an originating chapter on the elements followed by sections on the earth, air, fire, and water. It is a unique text that has been written within the past few years that doesn't loudly proclaim that it "has gone back to descriptive chemistry".

Admitting that a variety of non-mathematical approaches are possible in the "non-major" course, it is evident that the more arithmetically oriented the student is, the broader will be the spectrum of material that can be presented. Every encouragement should be given to the advisors in particularly the U.S. high schools to include as much math and science as possible for the student entering the college program, regardless of the ultimate goals sought by the student. At times it is necessary for us to make a decision as to whether one teaches "*what* we know" or "*how* we know it".

TOPIC 2. The adequacy of texts, manuals, laboratory workbooks for the non-major student.

The adequacy of materials is very much a function of the teacher. It is the obligation as well as the privilege of the teacher to add, subtract, and even correct materials that are found in current texts. Texts are designed or could be designed with two virtually orthogonal approaches for the non-major student. If we in general assume the importance of an environmental approach, it is possible to start with the basic chemical concepts and work in the environment as is appropriate; or contrarywise, to start with an environmental object or situation and use chemistry to explain phenomena. The latter virtually assumes a case study approach. A modular approach has been successful in teaching laboratory; why then could not a text be designed with a series of modules relating the environment to chemical phenomena? A partial answer to why such are not produced is simply financial. It does not seem that these modules would "sell". For those with long memories, there is the historical situation of the "paperback", which attempted to treat small units of chemistry, with a course then being based on a collection of these paperbacks.

A Japanese participant (YT) not only succinctly, but poetically, summarized much of the thinking in this matter of suitability of materials.

> "Your purpose should be to teach chemistry rather than to protect chemistry from the criticism of the general population. We must never forget that the necessary materials should be placed in the hands of the students so that they can manage to walk using a variety of paths to the foot of the mountain of chemistry".

TOPIC 3. The laboratory in the non-science major course.

Throughout the deliberations a recurring issue needs to be highlighted. In virtually every area, concepts introduced for the non-major seemed as often as not to be transferrable to the more science oriented student. Amongst a number of major differences between the Japanese and the American system, particularly at the introductory level, is the matter of laboratory. The difference starts within the secondary school where, as previously noted and will again be brought into focus, the Japanese student has received a far more intensive science and mathematics education than has his or her counterpart in the U.S.A.

Since the Japanese students feel that they have accomplished all the laboratory they need in the secondary school course, enthusiasm for laboratory beyond that level is minimal. It would be questionable to say that all American students moving from the high school to the college non-major laboratory course are imbued with great enthusiasm; however, in many cases, this will be the first and perhaps only laboratory encountered. Every effort should be made to produce the most meaningful and educationally sound laboratory that is possible.

Serious consideration needs to be given to the economics of the laboratory as part of the non-major course, whether in the U.S.A. or Japan. The Japanese, for instance, have as an option a Sōgō Kōsu, or a non-lab "Unified Course". It is well understood by all participants that the laboratory, regardless of the nature of the course, is an expensive contribution to total education. Cost/benefit ratios need to be considered.

TOPIC 4. Adapatation of techniques involving recent developments in technology (computers and other applications in instruction and learning, video and audio tapes, programmed instruction, peer instruction [Keller and other plans], closed circuit and other T.V. applications).

This topic was one of a number that represented a major shared interest.

The Japanese (TS) are strengthening their program in both computer assisted instruction and computer managed instruction through the efforts of the Japan Society for Science Education, established in 1976. The fact that some 50-percent of the papers at the last annual meeting of the Japanese Chemical Society's education program dealt with the use of computers is most significant. The introduction of computers represents a complete change in the educational philosophy from past times. The Japanese student appears to be more interested in a method of approach or "play" than the seeking of truths that arise from observation. It is a natural assumption that the methods of instruction should be re-evaluated and innovations should follow. The claim is made that computer-assisted instruction adopts more readily to large classes, since a more effective data-collecting procedure is available.

A very sophisticated approach in Japan using CAI was developed to evaluate achievement in the secondary school course with students using the rudiments of both the CBA and CHEMS approaches. It was possible through the use of this approach to evaluate the level of difficulty for all of the major topics studied in the secondary school chemistry course. There is no reason why this would be significantly different than the results derived from the tertiary introductory course.

In the Japanese approach there are still major difficulties to overcome. The software is anything but routine; the adaptation of the laboratory experience is far from perfect when sitting before a terminal. There are inherent difficulties in displaying Japanese characters, and finally, there is the perennial dollar (or yen) input. The Japanese have requested that an international program bank be established.

The capabilities now exist for an almost infinite variety of quizzing operations that would be part of a personalized system of instruction, as well as for more traditional courses. The obvious warning in the generation of such examination questions lies in the student becoming an automaton in problem-solving and less than proficient in reasoning and ability to communicate. Obviously, the computer is not only a tool for producing the examination, but also in grading and record keeping. The diagnostic process is used in a number of institutions developed by another of the participants (BZS). Almost daily progress the student makes in class work can be monitored with appropriate suggestions as to where help might be obtained based upon nearly continuous quizzing. This teaching and learning process is known in this country by the acronym CHEM TIPS (Chemistry Teaching Information Processing Service, J. Chem. Ed., 52 588 [1975]). In outline form, the computer serves some major functions:

o Remediation

Drill and practice, the basic tutorial computer-assisted instruction, and teaching of non-chemical skills, including math and related deficiencies.

o Administrative Functions

The preparation of examinations, homework, scoring of examinations, diagnosis of student deficiencies, record-keeping, and interactive testing.

o Simulation

Since the capabilities of graphics now exist in readily available form, pre- and post-laboratory instruction is possible, as well as instrumental simulations, microscopic models and industrial, environmental, and social problems.

o Student Programming

Students are coming to our classes regardless of the nature of the course with a variety of skills in programming. Student programs have been used to do such varied things as simulating the distribution and decomposition of DDT in an ecosystem. Obviously, there are ancillary chemical facts that have to be developed before a program can be written. Such a program construction is not different than a term paper, since a variety of skills have to be developed, but in addition quantitative material must be incorporated in the program. Just as a valid examination instrument needs to be thoroughly tested before presentation, so must a computer program be thoroughly tested.

A National Science Foundation supported program is now underway in this country, co-directed by two of the participants (JJL and JWM) that will result in a network of programs that will be thoroughly tested. The information so derived will be widely disseminated. It was the considered opinion of all of the participants in the Seminar that the three words in CAT or CAL be taken at full value. Computer Assisted Instruction or Computer Assisted Learning mean just that - the computer is to assist in the teaching, and not be the teacher. This comment arose from a program currently underway in this country in which a selected number of universities will be developing a course to be taught to engineers exclusively by computer. It was emphasized more than once that instructors should adapt to, but not necessarily adopt, instructional technology.

Students are influenced and benefit from a variety of techniques. It is a mistake for any one instructional tool to be solely adopted. Other techniques that were part of the Seminar discussion and which were demonstrated or illustrated include: video tapes in the color format (RCB) that could be used as a library of demonstrations (the need for live demonstrations is not neglected, but rather the aim is to give the opportunity to the student to see a demonstration a number of times at a more leisurely pace); audio tapes for the more pedantic and often assumed operation including stoichiometry, balancing of equations, nomenclature; the variations on 2x2 slides which could include a sound component. It is an important and not often appreciated part of computer instruction that the student is involved in an interaction rather than a passive process, which is the usual situation for video and audio materials. (Two reference sources that may be of interest to the reader are: Alfred Bork's "Learning with Computers", Digital Press, Bedford, Massachusetts, 01730, 1981; John Moore, editor, "Iterations: Computing in the Journal of Chemical Education, 1959-1981", Division of Chemical Education, Springfield, PA, 1981.)

A special use (JTM) of the computer is one that does not involve direct student interaction with the terminal. Rather, the computer is used to facilitate written materials that would result in the production of modules applicable, for instance, to the laboratory. A modular approach to laboratory would have major advantages over the classical manual operations, in that updating would be possible at whatever frequency is necessary to describe a change in a particular system or case study. A particular case study might be that of the effect of stratospheric ozone on chlorofluorocarbons. Such an experiment would probably need to be updated at least once a year if we are to examine the history of this environmental problem over the past decade. A current NSF-supported effort co-directed by two of the participants (JL and JTM) of the Japan/USA Seminar is involved in the development of software that will produce environmental case study modules for both secondary and tertiary level courses. The task of tracking and storing information on a large number of environmentally-oriented modules could be accomplished easily by the modern micro-computer; thus, a word-processing system is being investigated that can handle scientific texts, graphic systems, and is amenable to editing and maintaining a current status for each module.

The instructor, whether it be in the computer, demonstration, or other area of instruction, must always recognize the limitations of his or her audience. There is a vast difference between being entertained and being instructed. Before, during, and/or after any instructional approach, whether computer simulation or demonstration, it is necessary to be sure that there is established a basis for understanding.

A very consequential issue now facing the educational community, whether in the U.S.A. or Japan, is the curtailment or even elimination of funding in undergraduate education. The National Science Foundation has virtually ceased to exist as a unit capable of financing large-scale additions of hardware to the undergraduate instructional facilities of universities and colleges. Laboratories, resource centers, and other facilities equipped with computer must at least in the U.S.A. seek other funding sources, some of which are no more dependable than the National Science Foundation in our current era of diminishing financial resources.

TOPIC 5. Evaluation and testing instruments.

There were both similarities and differences evidenced in the evaluation processes used in Japan and in the United States.

An often used evaluation process in the U.S. institutions will be through verbal or oral questioning. A grade may in part depend upon the contribution that each member of a class will make. Dialogue between members of a class and the teacher is also common during lectures. It was stressed that, for historical reasons, the Japanese student is not likely to express an opinion during lecture in a large or even a small class. Such a basis for grading would be unsuitable. Japanese students are likely to resist venturing an opinion if he or she knows that they are not particularly strong in a discipline. The American student is not usually so inhibited.

Although not uniform, there is justification for the feeling that we (U.S.A.) are likely to overexamine, almost to the point of examining more than we teach. Virtually the opposite is the case in Japan, in part because of differences in the availability of supporting staff (graders) for large courses. Although the multiple choice examination is encountered in many levels of instruction in the United States, such an instrument is not frequently used in Japan. When large numbers of students are being evaluated in the research oriented institutions, a sufficient cadre of teaching assistants will be available to grade examinations based upon the problem solving and/or essay type. Both countries are moving in the direction of the most sensible application of computers in the testing process. The essay examination is especially amenable to a multi-pronged approach to the evaluation process. It is assumed that an examination should: (a) provide the student with an opportunity to tell what he or she has learned; (b) to provide the teacher with a mechanism of identifying his or her failures; (c) divide a course into units for study purposes, and (d) provide a total review of the course in preparation for a final examination. Variations are found in one or more examinations being replaced by a term paper. Other options for multiple testing is that of dropping one examination, using the average of the remaining exams. The ever-present problem of either grading on an absolute scale or on a curve seems to have no ready solution.

Since the student entering the university system in Japan is highly selected and has received the uniquely rigorous high school background in chemistry and mathematics, the need for a highly sophisticated and complex grading system does not seem to be necessary. A single examination plus a final seems to be adequate in differentiating abilities. The usual spread seemed to be approximately one-third in the superior, or "A", category, and the rest were Bs and Cs. It was also pointed out by the Japanese that their system of evaluation is in a state of transition. The exclusion of student enrollments has meant that some universities, private and national, are accepting students who , in other years, might not have been accepted. There will be a continuing need for new and more effective proficiency examinations. In view of the freedom within universities to establish their own educational plan, it is likely that the U.S. system of evaluation is far more interactive than that of Japan. It is not unique to find in the U.S. student body a fraction of the individuals who feel that the examination is in violation of their learning integrity. An examination may be a memorization test, and not one that establishes a capacity to reason. On the other hand, poor performance on an examination is sometimes rationalized by the student that the questions did not test basic learning. It is less than a uniform policy amongst the teaching faculties in the United States to deduct points from a given question for improper English or spelling. The Japanese feel that their students are capable of expressing themselves adequately in their own language. The Americans, unfortunately, cannot make that same claim.

Evaluation instruments for the non-major course can take a variety of forms that are essentially non-mathematical. A few are mentioned. In the "pseudo term paper" form, a class (RCB) can be asked to describe in perhaps no more than a page some twelve or more compounds about which they feel they have some knowledge that they did not have when they entered the course. These can be compounds known by trade names that fall into the pharmaceutical, fungicidal, herbicidal, macromolecular, nutritional, structural, fabric, to mention but a few. The student, even at this stage of sophistication, is able to either use the text, reference sources found at the library, or discussions with members of the faculty to discuss structure, synthesis, or extraction, as well as use and misuse. Another (WK) is to choose a series of forms of matter which may include compounds or mixtures and tell what they know about it now. Still another approach is to ask the student to put into the language of the complete non-science person an explanation of a phenomenon that might be recorded in the mass media. It is an obvious rule that the quickest way to learn something is to try to tell somebody else.

The micro or "mini" computer (Pet, Apple, RST-80-types) properly and imaginatively used opens new vistas in the evaluation processes, which in turn affects teaching methodology not only at the non-major but at any level. An earlier section (4) suggested the use of the computer in testing although such was not the major thrust of that topic or area. The opportunities for producing testing instruments, each different in the numerical component are virtually unlimited, especially for courses at the introductory level. As important as the production of the examination, is the fact that it can be graded within minutes of completing the exercise. Thus computer testing is almost a necessity if large numbers of students are to use one or another of the so-called self paced or personalized systems of instruction.

TOPIC 6. The interdisciplinary course or program.

Both countries have had a rich history in the development of interdisciplinary programs and continue to investigate new approaches.

The history of the interdisciplinary approach for the sometimes referred to "cultural" course has in some institutions enjoyed a high level of success. It is not essentially different from country to country. The success has almost without exception been attributed to one or perhaps two persons. Throughout the lifetime of the course, the enthusiasm of these few individuals (more commonly, one individual) is responsible for its success. With either the loss of interest or the transfer of interests by these (or this) individuals the course dies a slow and often lingering death. The primary problems that seem associated with the success of such a course are: (1) the basic training and nature of most instructors which must be highly specialized; (2) a limited perspective on the part of the instructor not conducive to the interdisciplinary concept; (3) the student clientele usually is of highly mixed background, as well as limited maturity. A suggested solution to the problem is to peruse essentially an interdisciplinary approach, assuming the instructor has the capability of incorporating a large number of interdisciplinary examples illustrating the major principles being taught. Members of the Seminar were of the belief that a single theme could be chosen for a course with the numerous basic principles relating to that theme being incorporated. There are obvious choices such as energy, with the multitude of ramifications that are chemically oriented toward this theme.

An interdisciplinary course produced for students at the upper division and thus similar to the Japanese "Senior level" course is not unique in the U.S.A. educational system. It should be mentioned that the Japanese College of General Education in certain universities is not entirely a so-called "junior" program. The third and fourth years, however, may be very limited in enrollment in the College of General Education. Interdisciplinary science can be, and is, given to such students. Several of these from both countries are mentioned briefly.

A junior or senior one credit course offered by one of the American participants (OTB) is essentially one of the history of science. A prerequisite is a history course, as well as one lab science course. The enrollment is largely from the humanities and social sciences. The major themes are: cosmology (from the Egyptian era to the Big Bang); atomism reverting to the Greeks and to electron structure; and finally, evolution, including astronomy, chemistry, biology, geology from the ancient times to the present. An opportunity is afforded in this course to stress the power of mathematics from the Babylonian contributions, the knowledge of the Pythagorian theorum, and on to the more recent mathematical patterns in electron structures. [Several references texts are noted. Th. Kuhn, Copernican Revolution; A. E. E. McKenzie, Major Achievements of Science; H. Butterfield, Origins of Modern Science. A number of the reprints in the Nuffield series are pertinent: Structure of Matter; Architecture of the Heavens; The Discovery of Time.] Not only in the interdisciplinary approach, but in others, the use of term paper assignments was notable. These papers varied from complete freedom of choice to a rather highly structured project with monitoring throughout the term. Such courses are successfully treated, as long as the aforementioned enthusiasm exists, often by a team approach. Unusual success has been achieved working with the Oriental disciplines, as well as other sciences and religions. What appears on the surface to be an orthogonal approach to "interdisciplinary programs" is to use an "adisciplinary approach". It would be possible to use both concepts. A name well known to the scientific and educational community, Joel Hildebrand, has defined the "scientific method" which, if followed, could certainly tell us much about the conduct of the course for the non-major. In his words, "to be successful in unlocking the doors concealing nature's secrets, a person must have ingenuity. If he does not have the key for the lock, he must not hesitate to try to pick it, to climb in a window, or even to kick in a panel. If he succeeds, it is more by ingenuity and determination, than by method".

To better understand the Japanese approach in either interdisciplinary courses or special instruction for the non-major, one must appreciate the fact that in the national or Imperial universities, the four-year course of university study is divided into two major branches. The junior level course (different nomenclature than that used in the United States) is essentially a two-year program that is conducted on the campus of a College of General Education, often physically separated from the "Senior" campus.(see earlier) Students completing this general college education would proceed to a second campus, which for the most part would be a collection of professional schools or departments. The latter is referred to as senior education. The experience of the Komaba College of General Education campus of the University of Tokyo is of interest since there are some changes in the philosophy in instruction over the past decade. The so-called arts students are supposed to choose two subjects out of a variety of science areas in order to satisfy a "group requirement". Some seven or eight different areas might be chosen; however, two of the most commonly chosen are chemistry and biology, apparently not because of an inherent love of the sciences, but rather since the high school or secondary approach has been so outstanding, the chemistry and biology in the first tertiary course may not be especially challenging. The result is no particular vote of confidence for our particular field. Two new subjects have been introduced to, in part, alleviate this situation on this campus. One is an Introduction to Science, a basic history of science, while a second is the Unified Course (Sōgō Kōsu). Since there are so many individual areas of science included in this unified course, the amount of chemistry is extremely small, some three lectures out of 25. The individual instructor may choose an area that he or she considers to be amenable to this brief introduction. A case in point is to explain some of the geometrical or "shape" concepts in chemistry. Currently, the unified course is heavily populated by the science-oriented student, and therefore, does not totally respond to the problem of a suitable course for the non-major. The first mentioned modified course "Introduction to Science" varies depending upon the philosophy of the lecturer for that course. It also will be a function of the textbook since in many cases they are written by the lecturers chosen to conduct the course. The content of most books is far less than a quarter of the total in chemistry. The clientele of the unified course varies from university to university throughout Japan, catering more to the arts students in some institutions than for others.

A three semester sequence of lectures (HH) is presented in Japan. The first series incorporates some of the geometric aspects of molecules, including confirmational analysis. The second is an exploration of molecular structure, with a major thesis being light and its absorption. The third is an interesting combination of molecular vibration and motion incorporated into a kind of ballet or dance production. This approach might be described as "Stereo dynamics". This last mentioned segment is reminiscent of a ballet of molecular reaction that was produced for an American Chemical Society national meeting (Baltimore) almost 40 years ago. It leads one to the conclusion that there is indeed a very large wheel that rotates, albeit very slowly.

A one semester course for non-majors developed over many years (AJH) for students who obviously are intellectually curious but not scientifically motivated is described. The course requires three lectures with demonstrations, one discussion, and three laboratory hours per week.

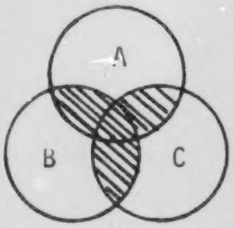
The course is focused upon surrounding phenomena and orchestrated about (1) forces between atoms to give molecules and ions, and (2) the forces between molecules and/or ions to give properties of macromolecules. Topics and principles essential to these themes are developed within the framework of this orchestration. By the end of the course, the student is capable of understanding to a reasonable degree the nature as we currently perceive it, of substances composed of large molecules and ions, such as polymers, both naturally occurring and synthetic.

The laboratory is dedicated to experiments, not exercises, and is designed to give the student the opportunity to have experience with the processes of science, including the uncertainties of measured quantities.

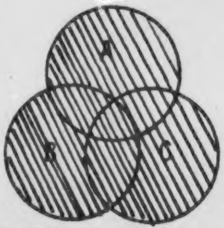
In both the lecture and the laboratory the quantitative nature of chemistry is always present, with primary emphasis upon the mole. The quantity of numerical calculations required of the student is restrained. On the surface, it may appear to be reasonably traditional, since amongst the topics included are the properties of the phases of matter, ideal and non-ideal systems, equilibrium, chemical properties, solution chemistry, pH, and bonding amongst the traditional topics that are covered, with kinetics and thermodynamics being slighted. The adaptation to the non-major is a function of the instructor's ability to "orchestrate" the process.

A possible single theme approach for an interdisciplinary course, a special symposium at a national meeting or any central theme could be an item possessed by virtually every student in every college, university, and in fact, school child in either country, the hand calculator. The various branches of chemistry, physics, metallurgy, ceramic engineering, polymer, the liquid state (e.g., liquid crystals), semiconductors, thin layer, acid etching, and basic electrochemistry could all be interwoven at whatever level of sophistication one wishes to choose.

Still another variation of the "disciplinary" theme is to consider a course as being multi-disciplinary, in which the difference is perhaps best noted in the following diagrams. It is obvious that we could use the term "disciplinary" theme is to consider a course as being multi-disciplinary, in which the difference is noted in the diagrams. It is obvious that we could use the term "interdisciplinary-oriented course"; however, the terminology "multi-disciplinary-oriented course" would not be proper.



Interdisciplinary
$A \cap B \cap C$



Multidisciplinary
$A \cup B \cup C$

As controversial as any item in this topic was the basic background of the students in the course, especially in mathematics (see 1 above). It would be difficult to make meaningful an interdisciplinary or multi-disciplinary approach to such topics as energy, environmental concepts including pollution without having at least some feeling for exponential numbers. The very concept of parts per million and parts per billion are absolutely essential if we are to incorporate any feeling for the levels of pollution.

A major contribution (HH) to the Seminar was one which interrelated chemical and mathematical thinking. Perhaps the level of reasoning needed to appreciate this presentation is beyond that of the usual introductory non-major course; however, the reasoning brought to focus through interactions of chemistry and mathematics as centered about structural formulas provides an instructive pathway. The basic concept is the assumption that there are two different ways for logical thinking, deduction and induction. Mathematics would perhaps be the most deductive, and chemistry is certainly very much more inductive. Even mathematics has been developed over many, many decades through repeated chains of both deduction and induction. Throughout history chemistry has depended upon the quantification needed to prove otherwise assumed existence of molecules and atoms and indeed eventually the fundamental particles of matter. It was not until the 19th century that topological approaches were possible through the insights of such memorable persons as Liebig, Kekulè, Franklin, Kolbe, Van't Hoff, LaBelle, and Fischer. Periodicity concepts of Lothar Meyer and Mendeleev also contributed. The importance of both graph and group theory to understand the structural and other isomeric forms of molecules , especially conformational analysis clearly relates mathematics and chemistry. The mathematical-chemical interface is elegantly presented in the full treatment of the Kekulè resonance structures of benzene. The reasoning applied to this system can be extended to the various mathematical features of structural formulae, obtaining a perspective view of chemical substances and chemical logic. The frontiers of electron theory of Fukui and the contributions of Woodward and Hoffman in their classification processes provide the mechanistic local information on the reacting species by the use of symmetry properties of the simplest molecular orbitals. Certainly the combined efforts of these three individuals is an outcome of successful chemical and mathematical thinking. The so-called non-major in chemistry certainly could be a highly mathematically trained and oriented person, but who has little information on the basic elements of chemistry. This kind of approach should not only be challenging but fascinating to such an individual. It is possible that the Seminar was devoted to too much in the way of energy and time to the person who is trying to avoid every semblance of organized thinking. The author of this presentation felt that it was our task to let the chemistry non-major student know that the way of thinking which chemists have used to construct modern chemical models has not differed greatly from what mathematicians and physicists do. The chemist prefers to play in the diversity or peculiarity of the world, rather than in the simplicity of nature. The importance of pure science should not be ignored or slighted in turning attention to the non-science student.

One cannot separate the ideas of interdisciplinary approaches from the "non traditional approaches" in teaching chemistry to the non-science oriented student. When either an interdisciplinary or a non-traditional approach is to be developed, one question deserves an answer: "What goals are to be identified that would differ such an approach or approaches from the traditional course"? Regardless of the course, the student must be provided an opportunity to discover that he or she can: (a) understand science, (b) learn about how nature behaves from a scientific point of view, (c) learn something of science independently, without specific instructions from the teacher of the course. These objectives are obtainable by a multitude of routes. A number of them have already been discussed. The single-theme approach was mentioned briefly in the non-traditional approach through a study of the "Elements". Thus, an interdisciplinary or non-traditional approach might evolve about the element sulfur in terms of its chemical, physical, nuclear, and radiochemical properties, its medicinal and biochemical functions, its industrial chemistry, including the economics of sulfur and its compounds. Obviously, the same general outline could be used for a wide variety of elements with the same or different ancillary topics.

Still in the nature of non-traditional approaches we find that a number of museums in the United States, as well as Japan, are taking a lesson from the Deutsches Museum in Munich, establishing exhibitions that are chemically oriented. Other disciplines have outstripped chemistry in this area of popularizing chemistry for the benefit of the non-science oriented citizen. Certain exhibitions are created for special occasions, such as one entitled "Chemistry for Future Life" in Japan. The exhibition includes a special collection of elements arranged essentially in a periodic table format. Special "button lighting" mechanisms will be used to highlight the chemical elements including a number of ancillary explanations in origin, reactions, and use. At the end of the exhibition, the collection will be donated to the National Science Museum of Ueno, Tokyo, Japan. This approach was one of several suggested. The use of travelling exhibitions, laboratories and instrumental collections, amongst others, is a way in which the central museum of a state or country may provide useful information in outlying areas where the general public would not be able to become involved in scientific processes. Not totally different in concept is the travelling "chemical show" originating at a state or private institution that would move into the outlying regions providing "attention getting" demonstrations and experiments at local high schools. Thus, formal course work within the university or college would not be the only approach to acquaint the general public with the importance of the scientific method.

Concluding this topic discussion, an outstandingly successful sequence of courses that are both in the non-traditional and in the interdisciplinary arena are offered under the Earth Science Curriculum Project (ESCP), the Interdisciplinary Approaches to Chemistry (IAC), and a special presentation on cosmology and evolution, including the ancillary and interrelated areas of geology, astronomy, biology, and chemistry, taught by one of the leaders of the field in the evolution of life at the University of Maryland, Professor Cyril Ponnamperuma.

TOPIC 7. The Science-Economics-Political Interface in the Instruction of the Chemistry Student.

There was general agreement that the properly taught non-major, as well as any chemistry course, would include the responsibilities of chemistry to the general public and would not exclude the international as well as the political interface. Questions that need to be addressed would involve the breadth of training for the teacher of such a course. In other words, do we have the time, expertise, or even the prerogative to discuss the oftentimes little appreciated factor in the international relations such as bargaining in the chemical market from a position of weakness. Can we teach enough of industrial processes for our students to appreciate the implications in our daily lives, for instance, of one nation cornering a market in such important ores or raw materials as bauxite, important alloying elements of cobalt, iron, wolfram, and nickel, to mention but a minute spectrum of chemical species. One of the most natural areas to weave the interface of science-economics-politics would be the general area of energy and all of its ramifications, certainly not limiting ourselves to fossil fuels.

The representatives of both countries in the Seminar agreed that it was neither desirable nor necessary to produce an entire course built upon this theme. It was noted in Japan that certain of these interrelationships came into play when the student was taught of the change from more easily obtained ammonium sulfate as a fertilizer to urea, which involved a new sequence of international and trade relations. The chemistry involved is not complex but is important in the fact that the soil of Japan was being destroyed because of lime being added to fertilized soil containing ammonium sulfate. The calcium sulfate was soon overloading the surface. Whatever the pollution of our environment, air, water, earth, it is obvious that pollutants are no respectors of international boundaries. One needs to look no further than the subject that has been with us for decades, but is only now receiving attention in the mass media, "acid rain". Additional opportunities for this kind of interaction are found in the last of our items for discussion noted just below.

As part of the interface, it is necessary that the student be made aware of potential implications when emotional issues are allowed to take over.

Although apparently remote from a course for non-majors, it was worthy of mention that both of our counttries have available for legislative consultation prestigious bodies. In the United States there is the National Academy of Sciences and in Japan the Science Council of Japan. It was a general feeling that if these bodies were properly consulted, many of the chemical-political problems could be at least brought to partial solution.

TOPIC 8. Case Studies as a Teaching Tool.

It was not difficult to find common ground for the two countries in instructional process when the subject of case studies and the environment were brought into focus. Not only were entire courses discussed at some length, but also the way in which otherwise theoretical material could be brought to life and into the real world by the appropriate use of case histories and case studies. It is not difficult to get a student's attention when you initiate a discussion that involves chemicals or other materials that directly affect his or her health and well being. A brief survey (MO) and summary of some problems that are concerns of the Japanese was presented. The participants (and the reader of this report) should make the obvious deduction that we are not that far apart in our problems. Our "citizen" must be made aware of the fact that chemicals in well defined quantity are absolutely necessary, but in the wrong environment or in excess pose a major problem. Chlorine as a war gas versus as a germicide is one example. Others would include morphine and heroin as pharmaceuticals and medicinals, but in excess and in wrong usage as "drugs" in the worst sense.

We easily invoke the mass media who often report on incredibly small concentrations of known carcinogens existing in materials surrounding us an involving ingestion (e.g., meat cooked via the barbeque route). The "zero" pollution syndrome is easily invoked. An excellent case of the application of some chemical principles to avoid a potential hazard is the replacement of benzene by toluene. The whole range of limits of purity can and should be illustrated by simple examples. A scientific demonstration is illustrative. Even the most elementary student can appreciate the fact that it is possible to precipitate chloride ion by silver ion. If such a precipitation occurs using treated potable waters it is obvious that we are not dealing with "a pure substance". If a solution is sufficiently diluted, then the addition of silver nitrate will not produce the visible chloride precipitate. All of the students, hopefully, will still say that the water is impure because of the excess silver nitrate added. A similar experiment with the iodide ion will drive home the fact that same concentrations of the two ions, chloride and iodide, will not result in the same observation when silver ion is added. A more sensitive device has been used with AgCl not precipitated but AgI forming a precipitate. Again, simple but effective detection and estimation devices such as paper chromatography can be used to prove that one chemical test is not necessarily adequate in proving or disproving the presence of a contaminant. The concept of significant figures and their meaning is evident. Credibility of science and necessarily of the courses we teach is often dependent upon understanding sensitivity of these pollution limits. Perhaps it is a problem in both countries for the scientists, particularly those involved in health and the environment to "get their act together" and establish realistic and meaningful limits. Even understanding significant figures will be of little use if the scientist does not provide realistic figures. The international and worldwide dimensions of chemistry are driven home when the environment is to be contaminated either through the oceans or in the air. The "citizen" is thus faced not only with domestic legislation, but international legislation (note [7] above). The role of the individual as opposed to or in conformance with the role of a total population is indeed another excellent example of the environment and its protection. A pollutant created by a single person or a single small functional group (school, home, factory) may be insignificant. Multiply this small fraction by an incredibly large number and the result may be catastrophic. The obvious chemicals that come to mind are carbon monoxide, oxides of nitrogen, oxides of sulfur, and the fluorocarbons. In this sense, the Japanese islands are extremely vulnerable, with a population of 110 million, where 70 percent of the land is not suitable for housing and only very small fractions of the land tillable. An important economic interface is obvious not only for Japan, with its high density, but with the United States, with its ever increasing population density. There is a time in history when we may well have to quell our desires for an ever rising standard of living, when these standards result in ever increasing pollution. Choices must be made. Those chemicals useful for purification (germicidal chlorination) may even become suspect when other reactions result that produce undesirable and harmful by-products. Our students in the so-called non-major course can easily be made aware of such ecosystems as the chlorination of hydrocarbons (in the just-mentioned germicidal action), the effluent phosphates that will lead to the elimination of our fresh waters as such, the increasing lead content due to the high automobile population. The economic aspects are clearly evident when the student realizes that an object worth $1.00 a decade ago may be on the market for $2.00 or $3.00 currently because of the extra costs in protecting the environment.

Certain already appreciated ideas are reinforced, especially those of non-problems of a decade ago becoming real problems in the present era and unfortunately virtually insurmountable problems in the future, without remedial steps. Not all problems appear to have answers. This leads to an uncomfortable situation amongst the scientific community, whether we speak of a teacher or a research scientist. Why, when we expect the student to come up with a "perfect" answer in an examination, can we not provide "perfect" answers to these troublesome environmental problems? Somehow, the student must be inculcated with the feeling that the so-called unanswerable questions may in time have answers if there is sufficient effort put into the solution. This solution is both one that is not only related to the financial resources of the country, but as well to the intellectual capacity of its citizens who are willing to spend the time and effort needed for the proper education.

The so-called "citizen" in our non-major course may hold the key to whether financial resources will be made available for the cure to problems. A well-known epigram is descriptive. "There are no simple solutions to our environmental problems ... only intelligent choices on what to do to work towards their amelioration".

There are many misnomers in the evaluation and treatment of environmental problems. In the truest sense, there is no such thing as hazardous waste disposal or even non-hazardous waste disposal. In fact, no such thing as waste disposal exists. There is such a thing as waste movement, as well as conversion of hazardous waste to something that is less hazardous. There is, further, the ultimate possibility and obviously the most desirable, the conversion of non-useful waste to useful materials. Each of these considered items involve monetary transfer.

A Japanese (TS) approach to building a course for the non-major has been keyed to natural substances and industrial products; that is, teaching chemistry in terms of the familiar materials in the real world. In this regard there is no difference in our two philosophies. The Japanese have in recent years encountered a student body with what appears to be an ingrained dislike, perhaps even hatred, for the physical sciences, particularly chemistry. This syndrome is not unique to Japan since the numerous environmental problems that seem to be related to chemicals and chemical systems is certainly influencing student bodies in U.S. institutions. A successful approach was reported in the modification of the orthodox teaching methods. A central theme was chosen - materials in everyday life. In so doing an instructional program evolved that made the students better understand the benefits to mankind, as well as the inherent problems that are associated with both by-products and over-use of chemicals. Among the many chemical species approached in this case study (or interdisciplinary program) were: the development of antiobiotics; chemistry and practical uses of vitamins and hormones (including the arithmetic that is necessary to understand the incredibly small amounts of what the public views as dangerous materials, parts per billion that are many orders of magnitude below acceptable levels); the famous Minimata disease; the poisons of the puffer fish; analgesics, including their history and derivatives; special applications of vitamin A in vision; special insecticides that are commonly used in the Japanese economy, such as the pheromone bombykol, its isomerism, quantities in the 10^{-20}gm L^{-1} sensitizing the male moth.

Still another case study (AK) is that of colloids and their effect on the environment. Colloidal phenomenon is a prime candidate for such an approach in the non-major course, in part because though not usually defined by the colloidal designation, these species are familiar to the life of all students, providing an excellent avenue relating chemistry and the real life about us. Unfortunately,very few textbooks devote more than a few pages to colloids and then usually in a section on solution chemistry. Since foodstuffs will usually strike a sympathetic chord for the student, a colloid is natural as an instructional tool (milk, butter, coffee, bread). Most of us engage in the classification of colloids as to whether they are gas-liquid, gas-solid, etc. Instead of the more common examples, the examples relating undesirable environmental situations would be more meaningful. A few situations are certainly obvious (foaming rivers, waste oil emulsion from discharge of tankers, turbid waste waters from sewage disposal, waste of the plastic foams). In order that we do not devote excessive attention to the undesirable and negative, obviously a number of useful colloids can be brought into a discussion (insecticidal sprays, cosmetic sprays, fire-fighting foams, emulsified agricultural chemicals, many foodstuffs, paint, printing inks, and synthetic leather). For the citizen (chemically oriented or not) there is the very practical (for the Isaac Waltons) application of turbidity by lowering a white plate into "fishing" waters thereby estimating clarity and possible inhabitability of fish. This subject can proceed very easily from the very highly descriptive to the far more mathematically exact treatment of colloidal particles in terms of their equilibrium processes, stabilization as a function of surface charge, the energetics of attractive and repulsive forces, flocculation based upon energetics, electrophoresis.

Such courses and the material contained therein form a basis for making many value judgments. When subjects of such depth and importance are brought into focus, the integrity of science must be maintained. It was agreed that integrity and in-depth, or rigor, need not be synonymous. Useful information that would fulfill the major demands and criteria of a course can be accomplished without a highly in-depth treatment of such topics. In any case study or specific topic brought into focus, there is always a risk/benefit analysis that must be made. It is impossible for the billions of people who inhabit this earth to exist without "pollution". The scientist and teacher at whatever level has the responsibility of providing information in a manner that is understandable not only to the members of his or her class, but to members of the general public. The responsibility includes not the positive but the negative impacts on society. The teacher, whether or not a chemist, is speaking as a member of the general public and has the same role as any other member of the public. It is not unique for the general public to be called upon to make judgments that the expert should be making. This ability is at the heart of the "reason to be" for the Seminar. It is neither feasible nor possible in either country for a single body, however great the collective expertise may be, to be consulted on every issue. If a course for the citizen has been taught with both integrity and imagination, the student will have a number of capabilities (though obviously not all that is needed) which might include an understanding of uncertainty in measurements as well as the basic information that will be needed to make the previously referred to risk/benefit judgments. There is ample history for persons being called upon to make judgments and to be swayed by the emotional rather than the scientific evidence. Among a multitude of areas that are especially vulnerable to the emotional approach would be nuclear power, the appropriate use of insecticides, herbicides and fungicides, as well as a variety of pharmaceuticals. It is evident that we are expecting a great deal, perhaps by orders of magnitude, from students being trained in our non-major type course.

A role that the instructor can play, however a course is designed, is to use current literature, even the daily mass media and point out bias or even better, ask the student to ferret out such bias as he or she might detect. There is a large difference between fact and opinion. This is another duty, indeed, obligation, attainable often by case study methods on the part of the science teacher, to aid the immature student to make such judgments. It is not an easy task to relate the magnitude of ink space in the media on a given issue to the true facts that lie behind a very controversial issue. It will be hard work to preserve the scientific integrity. The economic or aesthetic aspects of an issue are indeed important, but they must be labeled and kept differentiated from scientific evidence that is often difficult to present to the general public.

If we as teachers have a duty to aid the student in making a scientific and correct deduction from observations in the laboratory, then we have an equal opportunity, in fact, privilege, to help make deductions on issues of importance in the world about us. The case study approach presents a proper and exciting avenue. It is unfortunate that, at times, the scientist will speak out on issues that are outside his or her expertise, damaging the credibility of science and the scientist.

Both the interdisciplinary and case study approaches suggest a cooperation between the chemistry instructor and experts in the allied fields. We must be sure of the scientific content in areas outside of the expertise of the chemistry instructor.

As noted earlier, those chemical phenomena directly affecting life will be of great interest to the student. Such a case study is in carbon dioxide respiration and related buffer effects; the 7.35 pH of the blood, the equilibrium of CO_2 in aqueous solution to yield ultimately the hydronium ion and hydrogen carbonate ion, hyperventilation when carbon dioxide is lost so rapidly that it cannot produce the buffer system, cardiac arrest, in which hyper-acidity develops because of CO_2 is providing too high an acidity (recitifed by sodium hydrogen carbonate). Not unrelated is the anomaly of too much acid fruit juice providing for a basic blood condition through an interference with the acid phosphates serving as buffers in the bloodstream.

Still another interrelationship, a physical phenomenon, with chemistry is an often little appreciated fact concerning light and its role in atomic structure. It was Bertrand Russell who is credited with the observation that: with too little light, you don't see an object; if there is too much light, it is simply reflected from the object, which acts itself as a mirror, in which case we see the source of light and not the object. As is so often the case, we should operate in an intermediate range. Is this not a truth, whether we are dealing with light, instruction in chemistry, or the more general aspects of teaching.

There is a wealth of literature covering the general areas of case studies and interdisciplinary approaches.

Two reference sources are available for those concerned with the practical applications of chemistry. A cumulative index for 1964 to 1975 for the journal CHEMISTRY is available from the editorial offices of SciQuest. A set of brief encounters that involved so-called accidental scientific discoveries is available from the same source, authored by B. Schaar, "Chance Favors the Prepared Mind".

A complete curriculum has been described by Uri Zoller of Israel, which totally integrates environmental concerns in the training of undergraduates [Journal of Chemical Education 54 (7), 399-401, 1977.] Several cause and effect situations might be mentioned when "pollution episodes" are considered. The motorcar was at one time considered to be the answer to health problems that were related to the "after-effects of the horse". That such was false is certainly obvious. The modern water closet or toilet was another "salvation" to health problems. It is obvious that a whole new set of problems arose from water consumption and the effluent of the sewage system into water sources. Here, again, is the need for the cost/benefit analysis.

Amongst a number of published case study approaches are: a column "Science/Society Case Study" published in the Science Teacher, a journal produced mainly for the high-school chemistry teacher in the United States. The column was edited by one of the participants (JWM) and his wife. Included in the column were suggested activities to which students could be assigned as well as an annotated bibliography of more advanced articles covering the subject(s) and which would be likely to be available in high-school libraries. Among several other columns or sections of the Journal of Chemical Education, attempting to cover the real life of chemistry is one edited and written by another of the

U.S. participants (RCB) entitled: "Chemical Vignettes". Among a number of topics addressed were the importance of stereochemistry in pheromones; the fundamental chemistry of such common poisons as H_2S, CO, HF, HCN; the source of color aspect of our geology (strata, thermal mud pots); the energetics involved in the release of necessary alkali metal ions from clay minerals. Two other efforts are the "Chemical Principles Exemplified" and "Ecochemistry". There is an obvious deficiency in most of our textbooks, when we note that compounds or chemical speciesare described in virtually all their structural and physical glory, and yet oftentimes not a word is found with regard to their effect on the environment, including the human.

A cursory search of textbooks in the not too distant past, particularly in the organic field for a variety of chlorinated hydrocarbons, unearthed few that related detrimental physiological effects. More modern texts have made an effort to overcome this deficiency.

CONCLUSIONS AND RECOMMENDATIONS.

Whenever a group of individuals, however competent and dedicated in a field of endeavour, terminate an intensive period of consultation and discussion, there is a feeling of frustration, even inadequacy. If only the entire community of educators (in this particular instance) could have participated or at least been part of a listening audience! How can the multitude of worthwhile (to the point of exquisite) contributions be: (a) summarized, (b) succinctly encapsulated to a too short sequence of statements, and (c) circulated to those who will benefit? In certain facets of such a seminar approach it seemed that the wheel was being re-invented. A wheel is composed of many spokes and a rim, it may be that the spokes of the wheel were strengthened, the circumference of the wheel enlarged, thus resulting in a better wheel. There is no sin in certain truths and recommendations being re-stated.

Each full text, as submitted by the Japanese participants, as well as position papers prepared by both the Japanese and the Americans are part of a full document. The magnitude of this document prevents it from ever being produced for wide distribution. The major issues, summaries, and abstracts of verbal comments are found in the text of this particular manuscript. If the reader wishes the position papers and full text, the Principal Investigator (RCB) may be contacted. A copy can be made available for perusal or duplication if so desired, on the condition that it will be returned as promptly as possible. Steps will also be initiated to register the full document with ERIC (Educational Resources Information Center). Unfortunately, a period of some six months will elapse between the registration and the availability of the document from this center. Further information will be made available through the pages of THIS JOURNAL on the availability of the document.

1. It is critically important that both countries continue the search for the proper course or courses for the non-scientist, if we are to hope to have meaningful judgments made not only by the citizens of our countries, but also those who are the opinion makers, including legislators, managers, professionals of all kinds, especially those who are responsible for writing for the mass media. If such courses are to be developed, then those who are interested in their development need encouragement and support - against the pressures for security, stature, promotions via research, and conventional teaching for the major courses. Such teachers will be needing continued update through workshops or other media involving persons of similar minds. The source of useful materials, techniques available for teaching are not in general easily found or referenced.

2. Throughout the history of introductory courses we have been far more concerned with teaching the facts and theories to students than we have in inculcating attitudes. It is time to change the major emphases in our instructional programs. We hope that as a result of the deliberations of this Seminar we will have established a starting point if not change, at least to bridge what seems to be a gap between the facts and theories and attitudes.

3. A basic goal in our instructional program in the non-major tradition at whatever level of the college program should be one of contributing not only to the material progress of civilization, but to the mental and reasoning processes.

4. The secondary schools of Japan operate at a higher level in science and mathematics than do comparable institutions in the United States. It is strongly urged as a result of this Seminar that the science and mathematics pre-college programs be strengthened in this country to at least approach the rigor that is found in Japan.

5. Both the Japanese and U.S. secondary school teachers would benefit by the strongest possible education in the sciences and mathematics, particularly chemistry. It is a known fact that in the U.S.A the number of teachers going into secondary school science and mathematics teaching is dwindling to near the zero point. If we are to maintain the level of instruction in the tertiary first-year or introductory course, whether it be for the science student or the so-called non-science, or citizen, the best possible instruction is necessary. Whatever steps that are effective (lobbying is necessary) should be initiated to convice the U.S. Federal Government to fund special courses of instruction and institutes for the purpose of training and retraining science and mathematics teachers at both the secondary and tertiary level.

6. It is evident in the U.S. (to a somewhat similar though perhaps

lesser extent in Japan) that the reward system is woefully inadequate for the teacher at the tertiary level who is willing and who wishes to devote his or her academic career to instruction in the courses that followed the format of the Seminar. Such courses are often assigned to unwilling participants or are taught year after year by the same individual or individuals. Such is not in the best interests of maintaining freshness and vigor in any teaching program.

7. The laboratory for the kind of course that was the major theme of the Seminar is often either neglected or non-existent. The student who is not likely to take more courses in science is the person most needful of a laboratory program. Unfortunately, the decision is too often made that a laboratory is of little consequence unless extensive and highly technical experiments are being conducted. The simplest natural phenomena may prove to be not only illuminating, but exciting, to the introductory student, not wishing to make science a career. A laboratory component for the Japanese "non-major" course does not seem essential.

8. The importance of the processes of science and the contributions of chemistry to our material well being must be stressed for the non-major student. However, it was also important that students at all levels recognize the results of these processes. No apologies should be offered for the pursuit of science as a pure discipline; otherwise, we stagnate. Chemistry contributes not only to our material well being but to the mental culture of our civilization.

9. In both (Japan and U.S.) educational systems there is ample opportunity to develop non-major courses for clientele other than the student with little apptitude for mathematics. We may be expending excessive energy on this group. Certainly there are now courses in abundance for the student just entering tertiary education. More attention for instance might be given to the mathematically sophisticated student who is in a position to appreciate the

beauty of symmetry in molecular structure but who needs to know little if any synthetic chemistry or physical data interpretation. Far more cooperation is needed between mathematics and chemistry, biology and chemistry, and engineering and chemistry, to mention but a few interdisciplinary approaches.

10. Successful non-major courses have been woven about a multitude of single themes, amongst them; a single element, energy in any one of a variety of forms, one or more pharmaceuticals or medicinals, the colloidal state, and biological processes. The success of such programs is often directly related to a single innovator or individual. Unfortunately, the process or course diminishes or disappears from a curriculum when that person either leaves a department or persons of less competence and/or concern assumes the responsibility.

11. The large variations in approach make difficult the production of any single suitable text. The imagination and expertise (acquaintance with the literature) of the teacher dictates the proper printed material. The library must be used.

12. The world of computers is just now being opened to the students in the non-major (as in any instructional system). The need for mutual sharing of programs will increase and steps are being taken to circulate information. Diminishing costs of the hardware must be matched with suitable software. An inherent danger is recognized with a student (at whatever level) becoming dependent on another's innovation, thus becoming an automaton. Quizzes and examinations developed by this technology must not be of such a nature as to evaluate a student's ability to substitute numbers in exercises. Contrariwise, the horizons are unlimited in producing simulations to real life environmental problems, processes that will aid or assist (as in the A of CAI and CAL systems). The diminishing cost of hardware does not eliminate the current problem of diminishes (even vanishing) federal support.

13. Unique and effective evaluation instruments for the non-major students (in addition to the computer generated modes) include library research (or search) involving chemical species about which nothing was known before the course but now there is a degree of familiarity, critical evaluation of current popular literature for errors in facts of chemistry, chemical (real life) phenomena concerning which there is familiarity and understanding where there was none. Evaluation i the Japanese course structure especially at the introductory level is not as critical or necessary as it seems to be in the U.S.

14. Non-traditional and unique systems outside the walls of the college or university for education of the non-major are suggested. It is possible to make better use of science museum displays in chemistry to approach or exceed the effectiveness of those in physics. Inherent difficulties are recognized but solutions should be sought. Traveling laboratories and mobile groups that bring demonstrations to civic groups as well as secondary schools have proven effective and should be expanded. Such can be supported and organized by state or civic museums of naturel history or science museums.

15. Whenever and wherever possible in the non-major as well as the science oriented courses, the instructor, as expertise permits, should attempt to interrelate the world of economics and international political impact with chemical systems (natural products, ores, the environment, including pollution). In this as in any instructional process of case studies or an interdisciplinary approach, we must be sure of facts. The second (or third) discipline must be consulted frequently to either provide the facts or participate in the instruction.

Attachments, Position Papers, and Texts

As was discussed under "Plan and Development of Agenda", the participants submitted position papers as well as, in the case of the Japanese, full texts of presentations. The position papers were circulated well in advance of the date of the Seminar. Although the report included much of both the position papers and the full text, there is a wealth of material that can only be appreciated by direct consultation of these papers. They are listed by title, author, and by the topic number which is noted within the body of the report. Originally, a larger number of topics was included in the proposal itself, and therefore, certain of the position papers are ancillary to the major topic.

	Title	Author	Topic/ Secion of Report
1.	Chemistry - Mechanical, Organist, Magical, or What?	O. T. Benfey	Introduction
2.	University Education in Japan - Its General Background	Michinori Ōki	Introduction
3.	Chemical Education at the General Education Level - An Example	Yoshito Takeuchi	Introduction
4.	Chemistry for the Non-Science Student	John W. Hill	Introduction
5.	A Two-Semester Course for Non-Majors	Stanely Kirschner	Introduction
6.	What Changes in Distribution of Materials would be Desirable if a Two-Semester (or Term) Course were to be Taught for a Non-Major Student?	Marjorie Gardner	Introduction
7.	The Nature of Science Education: Implications for Communications Media	J. J. Lagowski	Introduction
8.	Goals of Science Education	Anna J. Harrison	Introduction
9.	Chemical Thinking and Mathematical Thinking	Aruo Hosoya	Topic 1
10.	The Question of Intensity Level in the Presentation of Material: Quantitative vs. Qualitative; Need for Math?	William F. Kieffer	Topic 1
11.	What Balance is Proper Amongst Qualitative Understanding and Precise Mathematical Development of Topics in Chemistry Courses for the Non-Major?	Marjorie Gardner	Topic 1

Title	Author	Topic/ Section of Report
12. What Secondary School Prerequisites Should the Student Bring to the Course (Math, Physics, Chemistry)?	Marjorie Gardner	Topic 1
	Richard W. Ramette	Topic 1
13. Instructional Methods Related to Class and Institution Size	Robert C. Brasted	Topic 1
14. The Question of Class Size	Stanley Kirschner	Topic 1
15. Are Current Printed Materials Adequate?	W.T. Lippincott	Topic 2
16. Are Current Printed Materials (Texts, Manuals, Laboratory Workbooks) Adequate?	William F. Kieffer	Topic 2
17. How Essential is the Laboratory?	Anna J. Harrison	Topic 3
18. A Laboratory for Non-Science Students	John W. Hill	Topic 3
19. Laboratory Programs in General Chemistry	Bassam Z. Shakhashiri	Topic 3
20. The Use of Micro-Computers in Chemical Education	John T. Shimozawa	Topic 4
21. Techniques and Technology	John W. Hill	Topic 4
22. Educational Technology	Bassam Z. Shakhashiri	Topic 4
23. Educational Technologies	John W. Moore	Topic 4
24. Evaluations and Testing Instruments	Anna J. Harrison	Topic 5
25. What Kinds of Evaluation and Testing Instruments Should be Used in Chemistry Courses for the Non-Major Student?	Marjorie Gardner	Topic 5
26. Interdisciplinary Programs	Anna J. Harrison	Topic 6
	Richard W. Ramette	Topic 6
27. Science-Economic-Political Interface Instruction in Chemistry for the Non-Major Student	Robert C. Brasted	Topic 7
28. Should a Course for Non-Majors Include a Science-Economics-Political Interface?	Marjorie Gardner	Topic 7
29. Scientific, Social, Economic, and Political Interfaces	Anna J. Harrison	Topic 7
30. Environmental Problems in General	Michinori Ōki	Topic 8
31. Chemical Knowledge and View for Natural Substances and Industrial Products - Approach from Familiar Materials from Everyday Life	Tetsuo Shiba	Topic 8

	Title	Author	Topic/ Section of Report
32.	Case Study - Colloids and Environment	Ayao Kitahara	Topic 8
33.	What Should We Teach? The Elements, the Most Fundamental Concept of Chemistry	Kazuo Saito	Topic 8
34.	Are the Best Ways of Using "Case Studies" of Environmental Impact Related to the Chemical Kingdom as Teaching Tools?	William F. Kieffer	Topic 8
35.	Using Everyday Encounters with Chemistry as Teaching Tools. Instruction in Chemistry for the Non-Major Student	W.T. Lippincott	Topic 8

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For discussion at the Japan-U.S. Chemical Education Seminar Fall 1981

Preliminary draft of a paper for the "Chemical Bonds" section of the Journal of Chemical Education.

A possible approach to an interdisciplinary course in the sciences.

Chemistry - Mechanical, Organicist, Magical or What?

Otto Theodor Benfey, Guilford College, Greensboro NC 27410

The chemist has usually looked to his neighbors for his models. Our subject, situated between physics and biology, has at times been thought of as dealing with mechanical systems similar to those of Newton's physics, at other times as being more closely linked to the biological notion of organisms. Physics and biology have recently met with problems. Physics has had to grapple with the puzzling phenomena of relativity and quanta and has had to give up the simplicity of Newton's world. Even before then, chance had already entered the world of physics as well as the recognition that nature preferred disorder over order. While these changes were moving physics away from its mechanical base, biology sought to adopt that base. It sought as far as possible to explain its observations in mechanical terms. The vitalist-mechanist debates have been going on for well over a cwntury, the recurring question being whether the "whole" - an organism - is more than the sum of its parts, or whether it can be fully explained in terms of its constituents, its atoms and molecules and their properties.

The editor of the "Chemical Bonds" column, in that column's inaugural statement(1) pointed to three major ways in which nature was viewed in the renaissance, the organicist, the mechanical and what he, following Kearney, calls the magical and which Debus has called the Chemical Philosophy(2).

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(1) Kirsch, A.S., J.CHEM.EDUC., 58, 200 (1981).

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2. Kearney, H., "Science and Change 1500-1700", McGraw-Hill, New York, 1971, chs. 1 and 4; Debus, A.G., "The Chemical Philosophy", Science History Publications, New York, 1977.

In the library of the University of Pennsylvania a display case holds original copies of some of the classic books of this third tradition and supplies the following commentary(3):

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3. Statement of the Hermetic tradition, University of Pennsylvania, 1981; courtesy of Arnold Thackray.

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see p.2A

This tradition arose in part from the feeling that earlier views were largely based on Greek, hence pagan notions and that the Judaeo-Christian view of matter was different. The sacraments implied the possibility of transforming matter into something more than matter; the doctrine of the holy spirit implies the ability to learn from inner experience; the creation stories suggest a common origin of the material world and man. Hence meditation, intuition and experiment were seen to play important roles in gaining knowledge. External studies of nature and intuitions regarding human nature mutually illuminated each other. Here was established a way of learning about the natural world as important as the role of reason.

The magical tradition was unable to flourish in the face of the success of the mechanical viewpoint developed among others by Galileo and Newton. Chemistry limped along through the

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The world of the sixteenth- and early seventeenth-century natural philosopher was one in which astrology and astronomy were hardly differentiated-both Brahe and Kepler cast horoscopes and indulged in general prognostication-and chemistry was as much an occult philosophy as an empirical science. Cosmic harmonics, astral influences, Neo-Platonic number mysticism, and the philosopher's stone were integral parts of the Weltanschauung of Paracelsus, Dee, Porta, Fludd and their contemporaries, and they perceived the universe as a "great chain of being."

Elements of this tradition of alchemy, natural magic, and Hermeticism included the search for sympathies and antipathies in nature and a stress on the likeness of man, the microcosm, to the macrocosm. Experience was emphasized as the means to proper understanding of nature, and through such a grasp of phenomena the magus gained control.

The Hermetic tradition, as curious as it seems from the modern viewpoint, represents another thread which was woven into early modern science. Until recently neglected in the history of science, it was an inseparable portion of the intellectual climate of the times, with an appeal that was both wide-spread and long-lived.

iatrochemical and phlogiston periods until John Dalton placed chemistry apparently on the mechanical track. However, Newtonian physics was never able to explain the specific and limited affinities between like atoms. Why should identical hydrogen atoms have an attraction for each other, and if they do why don't we have H_3 and H_4 molecules as well as H_2? The answer only came through quantum theory, beyond and different from the Newtonian viewpoint.

During the nineteenth century, ever more problems arose that the mechanical assumptions could not readily accomodate. Faraday introduced the field concept to explain magnetic phenomena; the second law of thermodynamics postulated a direction in time for natural events - towards ever greater disorder - and around 1900 came relativity and quantum theory.

There have been suggestions that the physical sciences must return to the organicist analogy of Aristotelian and medieval physics. Joseph Needham (4) has claimed that Chinese science, as long as it was uninfluenced by the West, that is until the 17th century, was strictly organicist. The Western mechanical tradition was introduced into China almost as soon as it was developed in Europe but seemed to have met with considerable resistance. Needham suggests that Western science is now recognizing its need to return to an organicist viewpoint, that the mechanical analogy was perhaps a necessary detour but was certainly not the final answer. There was however another aspect to the Chinese viewpoint. Their recognition of the necessary coexistence of Yin-Yang polarities in all aspects of nature, night-dark, male-female, growth-decay and so on, suggests an intuitive combination of opposites, hence an affinity with what we have called the magical viewpoint.

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(4) Needham, J., "Science and Civilization in China", Cambridge University Press, Cambridge, Vol.2, 1962 pp. 291-294, 493-505; also in abridged form in C.A.Ronan, "The Shorter Science and Civilization in China", Cambridge University Press, Cambridge, Vol. 1, 1978, pp. 166-169, 246-249.

A.N.Whitehead in our century has suggested that the atom and molecule of the twentieth century are more analogous to the biological concept of an organism than to the classic Greek idea of a particle. Physics, he suggests, deals with small organisms, biology with the larger ones. Chemistry once more belongs in between (5).

Recently, Elsasser, in a book entitled "Atom and Organism", points out that organisms as now understood have both mechanical and organicist aspects, that we must learn to accept each in its particular area of applicability and that their combination cannot be done rationally, it requires the biologist's intuition. The book, which is largely a sophisticated argument relating and contrasting theoretical biology and quantum physics, ends with a sentence pointing us once again to the magical tradition requiring of us openness, creativity and intuition. Anyone dealing with the complex questions of modern biology "in addition to being a scientist, should have some capabilities of intuition, perhaps on occasion a little bit of the poet in him, if he is to apprehend clearly the intricate marvels of Creation."(6).

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(5) Whitehead, A.N., "Science and the Modern World", New American Library, New York, 1948, p.105.

The intuitive element, the basic presupposition or motivation of the scientist, the fundamental way he looks at his work, has also been stressed by Holton. He points out that in addition to his data and analytical work, a scientist operates in a third, the thematic dimension. Some scientists, as in certain interpretations of wave mechanics, think in terms of all things being continuous, others in terms of atomism. Newton thought of light as particles, Huyghens as being a wave disturbance. Other pairs of contrasting thema are constancy and change, complexity and simplicity, wholes as being equal to or greater than the sum of their parts (7). The contrasting thema of continuity and discontinuity have been examined in detail by Mendelsohn(8) who has correlated them with religious, political and social developments.

For centuries people have tried to argue one thema against another, that light was *either* particle or wave, and only in our time have the sciences become open to the possibility that both thema and antithema (Holton's word) might have their place in a mature science. Niels Bohr most forcefully has argued the need for both particle and wave views as necessary for a full physical understanding even if they cannot be combined into a single rational system. He has used the term *complementarity* to characterize such situations. When awarded the Danish Order of the Elephant in 1947, Bohr chose as his coat of arms the Yin-Yang symbol (Fig.1) with the phrase *Contraria sunt Complementa* (contraries are complementary). Bohr was leading us back (or forward) to the insights of the magical tradition that we must accept as true even certain ideas and facts that do not rationally fit together(9).

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(6) Elsasser, W.M., "Atom and Organism: A New Approach to Theoretical Biology", Princeton University Press, Princeton, 1966, p.137.

(7) Holton, G., "Thematic Origins of Scientific Thought", Harvard University Press, Cambridge, 1973, ch. 1, esp. p.29.

(8) Mendelsohn, E., "The Continuous and the Discrete in the History of Science" in "Constancy and Change in Human Development", O.G.Brim Jr., and J.Kagan, Editors, Harvard University Press, Cambridge, in press.

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(9) Holton G., *op.cit*. ch.4, "The Roots of Complementarity"; the coat of arms is shown on p. 123. (see this ms. p. 16).

Even though most people think of physics and chemistry as still solidly resting on a mechanical foundation, an analysis of current theories and how they developed from simpler formulations will demonstrate the presence of all three traditions, the mechanical, organicist and magical.

Suppose we examine what has happened to our concept of the molecule in two areas of physical science, the kinetic theory of gases and the structural theory of organic chemistry.

To understand the behavior of gases in terms of Newton's laws of motion, gas molecules were first thought of as point particles (symbolized as *N* for the concept Number) that move in space (3*D*) and time (*t*).

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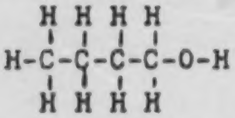
g.2 In figure 2 these six concepts appear in three pairs on opposite sides of a cube, one pair concerned with space (3*D*/3*d*), one with time ($\underline{t}/\bar{\underline{t}}$) and one with the discrete/continuous, part/whole, particle/wave dichotomy (*N*/*A*).

When I analyzed twenty-five years ago the structural theory of organic chemistry, a molecular model system aimed at predicting the number of isomeric substances of a given molecular formula found in nature, I encountered to my surprise the same six concepts found in kinetic theory.

The original 1858 theory of Kekulé and Couper did not even require space dimensions. It merely specified the valence of atoms, a numerical property (*N*) - 1 for H and Cl, 2 for O and S, 3 for N and 4 for C - plus the realization that carbon has a peculiarly powerful capacity to form chains. Our usual formulations such as 

$$\begin{array}{c}\text{H}\ \ \text{H}\ \ \text{H}\ \ \text{H}\\ \text{H-C-C-C-C-O-H}\\ \text{H}\ \ \text{H}\ \ \text{H}\ \ \text{H}\end{array}$$

suggest spatial arrangements but we chemists know better and often have difficulty convincing students that a carbon chain C-C-C-C-C is not in fact linear. Three-dimensional space did not enter the structural theory until van't Hoff and leBel in 1874 introduced the 3*D* concept of the "tetrahedral carbon atom", specifying the direction of the bonds from carbon in space.

Figure 3

This conceptual extension was made necessary to account for the difference in properties between natural products and their synthetic equivalents made in the laboratory and of the same "structural formula" (but without specifying bond-directions in space). The synthetic material was now seen as a 50:50 mixture of the natural substance and of its mirror image isomer.

Almost fifty years later, the isomerism of certain ortho-substituted biphenyls led to the realization that bond direction in space was not enough to establish a 1:1 correspondence between isomer number predicted and the number of substances actually found in nature. In the biphenyls, if A and B are hydrogen and iodine, two optically active isomers can be isolated but if they are hydrogen and fluorine, only one, an inactive one is found. The bonds (and their attachments)hence had to have volume, a space not available to other bonds and atoms and varying from element to element. (The iodine atoms are too large to allow free rotation of the benzene ring A space-filling property 3d thus entered structural theory.

Figure 4

The 3D and 3d extensions successfully explained anomalies where more isomers were found than predicted. Sometimes, however, fewer isomers are isolated even after extensive search. Resonance theory, for instance, explains why only one o-dichlorobenzene is found when two are predicted, one with a single bond between the substituted carbons, the other with a double bond.

Figure 5

Where two structures differ only in number of bonds while atomic locations are not significantly altered, then only a single substance is found. For certain structures, insisting on integral bond units ($\underline{N}$) is an error. Molecular orbital theory coalesces benzene's three double bonds into several six-center molecular orbitals, wiping out the atomistic individuality of the bonds. Resonance ry thus introduces the $\underline{A}$ concept.

There are cases even where no substances are found corresponding to plausible structures. Vinyl alcohol CH_2=CHOH used to be the classical example but it has now been isolated. These substances if and when found are highly reactive and unstable, and quickly change to alternative structures (in the vinyl alcohol case into acetaldehyde CH_3CHO). Here directional time $\underline{\vec{t}}$ enters our theoretical framework. Substances can only be identified if they do not convert too quickly into others. The sixth concept in our set, reversible time $\underline{t}$, appears in the spectral signals of organic materials, for energetically excited molecules revert back to the ground state with the emission of characteristic energy photons (11).

If space dimensions turn our molecules into architectural structures, the incorporation of directional time must transform molecules once more. They now turn into entities with a life-history, from their birth when they adopt the structure that determines their identity, through their life span with all the buffeting they receive which rotates, vibrates, stretches, bends and excites them, to their final farewell when they are fragmented, substituted, absorbed or metamorphosed to enter the life-history of another chemical species. Here we are very close to the language commonly used in the description of organisms.

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(11) Benfey, O.T., "From Vital Force to Structural Formulas", American Chemical Society, Washington DC, 1975, pp.104 ff. For an early formulation see Benfey, O.T., J.CHEM.EDUC. 34, 287 (1957).

I have since analyzed a number of theories, such as the concept of the gene, the atom, the biological cell, stars, galaxies and geographic continents. Continents were once taken to be rather dull, unchanging geographic entities but, thanks to Wegener's work and the resulting theories of continental drift and plate tectonics, they too have come alive, they break up and fuse together and are part of an ongoing evolution. Similarly our picture of atoms has changed from their being uncuttable billiard balls to their current image as complex structures formed at a certain stage in evolution and transformed by fission, fusion or absorption into atoms of other elements. They too have a life history and we have adopted biological, organicist language when we speak of the half-lives of radioactive species(12).

If we examine Figure 2, we notice that the three concepts needed for the original thoroughly mechanical kinetic theory, *N*, 3*D*, *t* (particles, directional space and reversible time), appear as three faces sharing a vertex. The remaining three faces - directional time $\vec{t}$, inner structure 3*d*, and continuity or wholeness *A*, sharing the opposite vertex, are characteristic concepts of the organicist tradition. If we look at opposing faces, we find that they cannot easily be incorporated in the same rational viewpoint. They correspond to contrasting thema and in fact represent the great riddles and controversies in the development of modern science. The $\underline{t}/\vec{t}$ pair appears for instance in the first and second laws of thermodynamics, the step from energy conservation to the inevitable degeneration of energy to heat. The $\underline{N}/\underline{A}$ pair is most famous in the wave/particle dualism of quantum mechanics. The $3\underline{d}/3\underline{D}$ contrast covers the questions whether the whole is simply the sum of its parts and in what sense the complex can be explained as emerging from simpler forms in evolution.

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(12) Wegener, A., "The Origins of Continents and Oceans", Dover Publications, New York, 1966; Takeuchi, H., Uyeda, S., Kanamori, H., "Debate about the Earth", Freeman, Cooper, San Francisco, 1970.

Almost without being aware of it, the modern scientific movement has incorporated the magical and organicist viewpoints into its current formulations. This is a discovery we need to incorporate into our teaching, first, that our entities - atom, molecule, bond and so on - are only in part mechanical entities, that they also partake of organic properties. Even more importantly we need to emphasize the lessons of the magical tradition - that rational coherence is not the ultimate criterion. Aristotelian physics was highly rational, yet wrong. Experiments can negate elaborate theories or force major modifications. And sometimes we must live with two irreconcilable facts or theories because giving up one or the other member of such a pair would be false to our full awareness of the mystery of the natural world. The organicist aspects of the material world should make us more aware of and sensitive to that world, should make us realize that it is not very different from ourselves, that it and we have our being through the same evolutionary process.

The "magical" aspects, the modern echoes of the "chemical philosophy" should teach us humility, the limitations of reason, and the need always to remain open to new observations and insights, no matter how difficult they may be to reconcile with our currently accepted viewpoints. We must always be ready to give up our cherished ideas and grow.

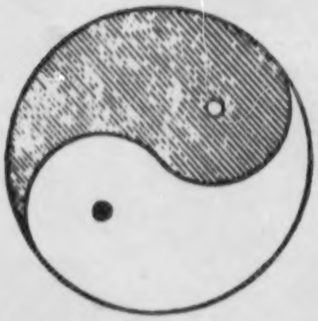


Figure 1 The Chinese Yin-Yang symbol, representing the necessary coexistence of opposites. Note the circle of Yin in the field of Yang and vice versa.

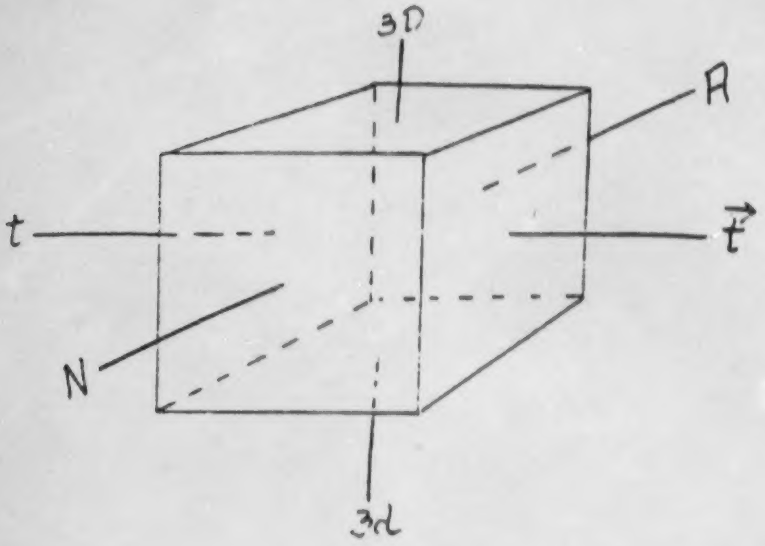


Figure 2 The Chemist's Solid Mandala - the six central concepts arranged in the form of three pairs

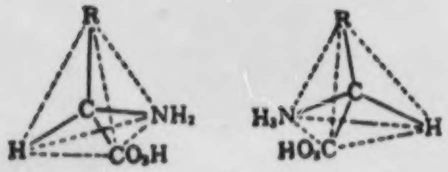


Figure 3 The three-dimensional representation of amino acids found in proteins - and their mirror image forms.

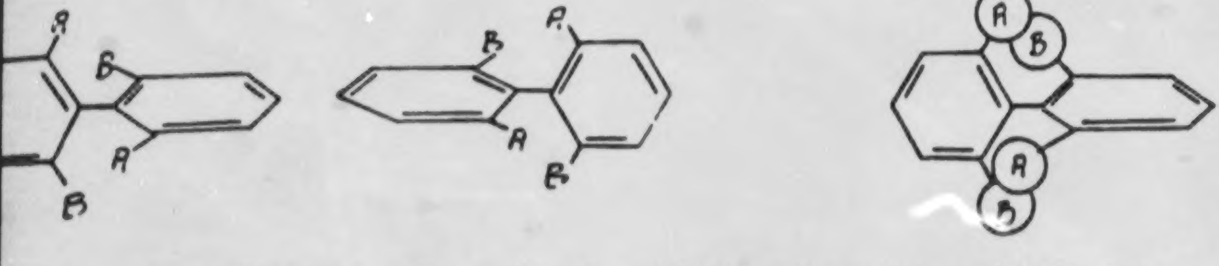
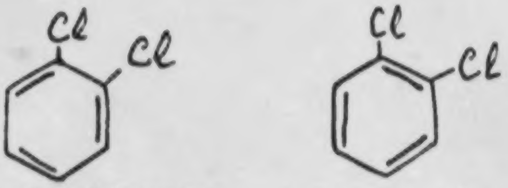


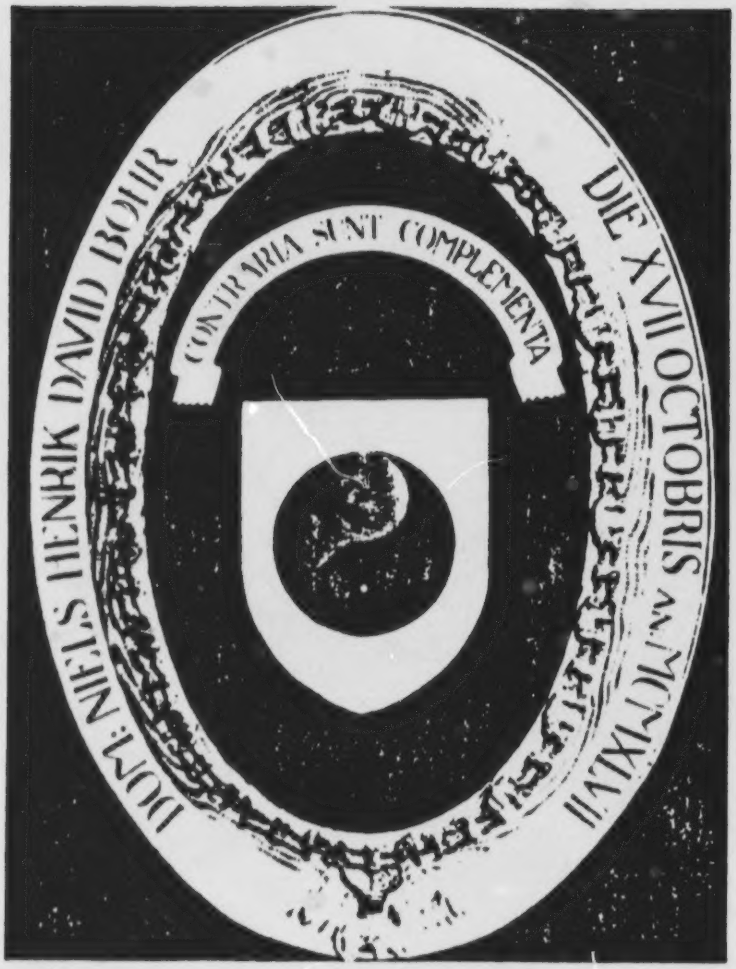
Figure 4 The optical activity of certain substituted biphenyls is due to the restriction of free rotation when groups A and B are too large.



single bond between substituted carbons

double bond between substituted carbons

Figure 5 According to resonance theory isomers differing only in number and location of bonds (and not in atomic position) cannot be found.


DOM: NIELS HENRIK DAVID BOHR
DIE XVII OCTOBRIS AN. MCMXLVII
CONTRARIA SUNT COMPLEMENTA

Coat of arms chosen by Niels Bohr when he was awarded the Danish Order of the Elephant, 1947. From Stefan Rozental, ed., Niels Bohr: His Life and Work as Seen by His Friends and Colleagues (New York: John Wiley & Sons, 1967).

-2-

University Chemical Education in Japan ——— Its General Background

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After World War II, Japan basically adopted the educational system which had prevailed in the US. Therefore the educational systems in both countries are generally the same. But there are some points differenct from each other. We should like to comment on a few such points. They are, for example, devotion to technological and engineering education in a part of high schools, the existence of departments of applied chemistry, and keen competition for getting enrolled in prestigeous universities.

The items which should be taught at high schools are determined by "the Course of Study" which is set by the Ministry of Education. There is only one kind of the content specified by the Course of Study. This causes, on one hand, troubles in less talented students in high schools but , on the other, is good on the stand point of the academic life. Mathematics in Japanese high schools are of rather high quality.

In addition, all the universities, private, local-governmental, or federal, give entrance examinations to the candidates. This system has an advantage in that the level of enrolling students can be made more or less uniform. For example, chemistry in high schools is elective in principle but universities can request to study chemistry by giving examinations of chemistry.

Usually more students apply to prestigeous universities than available seats. Therefore, university professors say that they have to give sequential numbers to applicants. A problem of chicken and egg had occurred: applicants to prestigeous universities prepare hard to win the competition and the universities prepare harder and harder problems so that not many applicants get full marks. The issue of the entrance examination became a social problem. As an answer to the problem, a common examination for the entrance to tertiary education is now given which will be discussed in some detail.

Chemistry is very unpopular in Japan. Chemistry is a troublemaker for the general public. If a university selects students on a departmental basis, it is not expected for chemistry departments to have many good applicants. If a university selects students on a faculty basis, good students may select biological science or physics department when they finish general education: many chemistry departments suffer from shortage of students relative to available seats.

Under these circumstances, we are repeatedly asked "why do we teach chemistry?" It was true that, twenty years ago, chemistry was taught to raise chemists of next generation, but today we teach chemistry to vast number of students. Majority of students may not become chemists. We are asked to think that teaching of chemistry requires new philosophy. Many of Japanese educaters

University Chemical Education in Japan
—— Its General Background

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1. General Aspects of Education in Japan

Generally speaking, the Japanese system of education is similar to that of the US because we adopted recommendations from the US after World War II. However, if we look into details, we notice differences between the two countries. The differences originate from the traditions in Japan which prevailed in the past.

The idea of general education was brought into the system. Indeed, normal high schools are most popular among various courses in upper high schools and students had been required to take general education courses in colleges before studying their specialized courses, although the latter system was changed to some extent as is mentioned later. However, Japanese had had a traditional thinking that "you should be accustomed to do so rather than you learn how to do it." This must be the origin of Japanese handicrafts which receive admiration from the world. Therefore, there do exist various school systems which give courses of technical training both in high schools and in colleges even today.

Vocational schools hold popularity in this respect as well. Vocational shools are the places where technical training rather than general education is given. They have been strong even in the days when general education has been the main stream and are becoming even stronger for these days because students can get necessary skills in shorter periods for working in firms. Vocational schools which give training of computer operation are the most popular for these days.

As for chemistry, there are several courses in high schools which give special training. They are industrial chemistry courses in technical high schools and science-methematics courses which are generally attached to normal high schools. In agricultural high schools, they give courses of chemistry of insecticides etc., whereas in industrial chemistry courses of technical high school courses such as inorganic, organic, and analytical chemistry are required. The science-mathematics courses are rather new. There are about 100 classes in total. They give intensive training in mathematics and natural sciences. The credits for these subjects required for graduation are generally twice of those in normal high schools.

Chemistry departments are instituted in various faculties in universities. Faculty of science institutes chemistry departments which are generally concerned with pure science. Some of faculties of science institute biochemistry departments. Faculty of engineering institutes various departments such as industrial chemistry, applied chemistry, petroleum chemistry, polymer chemistry, chemical engineering and others. There are other faculties which also insitute chemistry departments. They are pharmaceutical sciences and agriculture. Therefore, it is not surprising to see several chemistry departments in a university. In departments of chemistry, the curricula are more or less similar with those in the US but, in departments in faculty of engineering, they are more industry oriented. It must be mentioned here that, in these days when graduate school training has become more popular, the difference between faculties of science and engineering is becoming less, but it seems that there still exist the difference expressed by "pure and applied chemistry".

The enrollment at upper high schools amounts to 94% of the same age. That means that the high school education up to the age of 18 is almost compulsory for Japanese. More than 50% high school graduates, including those of technical and other high schools, apply for the entrance to universities and colleges (including junior colleges). About 37% of the whole population goes to universiteis and colleges, of which 28% to 4-year colleges. The number of universities and colleges in Japan supported by the federal government is 86 and there are fewer number of local-government supported universities and about 700 private insitutions. However, the number of students who are trained in private insitutions is rather small in natural sciences because of the cost of education. The main source of science graduates is therefore federal government supported universities.

The existence of another system of technician training must be mentioned here. In 1960's, a number of technicians was required by industries when they expanded rapidly. The quality required was rather high at the time. Japanese government decided to establish a new system which is a through-education from the age of 15 to 20. The school is called a technical college. The graduates of the college were highly welcomed by the industry in 1960's. The situation has changed since then. On one hand, our industry has become to recruit technicians of even more high quality. On the other, many of the graduates from the technical colleges became to hope to receive further education. Although some of universities accepted applications at their faculty of engineering, the number was still limited. To meet the demands from both sides, there are now two 4-year colleges called universities of science and technology which institute graduate schools as well. Although these institutions accept students from normal high schools also, the main purpose is to educate the graduates of technical colleges further.

Japanese people are in a sense hungry always. They have been defeated by alien cultures: by China 1500 year ago, by western Europe 100 years ago, and by the US 30 years ago. They have never been satisfied by their traditions. The same can be said for their living. They always aim to upgrade their living standard. It was essential in the past for the people to be graduated from a well-known universities to get a good job and to become directors in industires. Therefore, parents wish to send their children to renowned institutions. But the number of seats available in these renowned institutions is of course limited. Because of the keen competition, many began to think that, inorder to win the competition in the college entrance, their children must prepare for the entrance examination as low age as the elementary school days.

This kind of thought brought another problem. That is, everything which is disadvantageous for the competition in entrance examinations of universities and colleges is ranked low. For example, the technical high schools became unpopular because they give extra training such as analytical chemistry which is not required in the university entrance. This trend induces trends to consider that normal high schools are better than technical high schools. Local governments which are usually responsible in founding high schools could not afford to meet the demand of the parents. A number of private schools have been founded in this respect. But, as everybody accepts, everybody cannot be a genius. A high school which sends many graduates to renowned institutions has become given a credit of good school. This induces competition to get into good high schools. The trend continues to involve lower high schools in competition and then even elementary schools. Inteligents warn the dangerous nature of this kind of competition but it seems that a long time is necessary to subside the competition. This kind of competition cannot be forgotten in discussing education in Japan.

2. High School Education and General Education in Colleges

The curriculum in high schools is controlled by the Ministry of Education. The Ministry of Education issues the Course of Study which is usually revised every nine years in recent years. Text books which must be used in high schools are edited by specialists and published by private publishers. The text books receive inspections of the Ministry of Education which judges whether the text book is in conformity with the contents shown in the Course of Study. The text book which is used in a given upper high school is selected by teachers of the school.

A new Course of Study was issued in 1978 for upper high schools and is to be enacted from the new comer to the high school in 1982. Therefore, today is a transition time from the old to the new curriculum. This change deserves mention. It is the intention of our government that the level of education is set by the national standard. It may be true that, if we consider our Constitution which states equal opportunity of education is provided for everybody, all the nation has a right to be educated under a single Course of Study. The system also has a strong point in that the level of education is not dependent on schools or districts. The other extreme, that is no control of education by the government, can be seen in various advanced countries but they suffer inequality of the level of education. External examination and inspector systems in the UK may be taken as a means of try-outs for assurance of the equal level.

The equality under the Course of Study, however, causes another problem. It was good when fewer people enjoyed higher education. But nowadays the high school education is almost compulsory. Yet the content of the Course of Study must meet the demands which occur from various backgrounds. If one speaks from the view of raising scientists of the next generation, one may insist that the energy level of electrons in atoms must be taught at high schools. However, that kind of subject is too difficult for general public and is useless in daily life. Therefore, easier treatment of scientific matters must be considered on the stand point of general public.

The revision of the current Course of Study took place in the midst of this kind of controversy. It was necessary to consider either plural streams of the course of study or a system in which a wide variety of selection is possible according to the will and the talent of a given student. Our government decided to widen the possibility of selection of subjects rather than to set more than one course. Thus only four credits of science are now required for graduation from upper high schools, instead of six credits in the old system. The same is true for mathematics. It may be better to discuss the new and the old Course of Study here, but because of the limitation of space only the new system will be presented here.

A course, called mathematics I, is the required subject in upper high schools. Its credit is 4. It encompasses number and formula, equations and inequality, functions, and trigonometry and functions representing figures. This subject is taught in the 10th grade, the first year of the upper high school. There are four elective courses to be studied after mathematics I. They are all 3-credit courses and are mathematics II, algebra and geometry, basic analysis, differential and integral and probability and statistics. Mathematics II is designed as a course which is studied by those who are not talented in mathematics but are interested in studying mathematics to some extent. It includes probability and statistics, vector, differential and integral, series of numbers, functions, and electronic computer. In algebra and geometry are included curves of secondary degree, vector in a plane, matrix and 3-dimensional figures. The basic analysis covers series of numbers, functions such as exponential, logarithmic, and trigonometrical, and changes in function values introducing differentiation and integration. It may not be necessary to mention differential and integral, and probability and statistics in detail.

In science, a course called science I is a required subject. It is a 4-credit course as well. It is an integrated science course and encompasses force and energy, constitution and change of matters, evolution, balance in nature, and relation between the mankind and nature. This course is generally given in the first year. There are five elective courses after science I. They are science II, physics, chemistry, biology, and earth sciences. These courses are of 4-credits except science II which is a 2-credit course. Science II is a course provided for those who are not talented in science but have willingness of studying science further. It is recommended in this course to study nature or a given phenomenon with the background obtained in the study of science I. It is also possible to study cases of science history in this course.

Physics include force and motion including various motions, momentum and kinetic motion of molecules, waves of sound and light, electricity and magnetism, and atoms. Atoms include charge and mass of electron, wave nature of electron, particulate nature of light as well as structures of atoms and atomic nuclei, and radio activity and nuclear energy.

Chemistry is divided into 4 portions. The first portion is concerned with chemical properties of matters. Items included in this section are inorganic materials such as elements (simple body), compounds and identification of ions, organic materials, and polymers, both natural and synthetic. The second is concerned with the state of matters. The concept of purity, three states of matter, and mixtures including the concept of partial pressure, solution and colloid solution are the topics here. The third is chemical reactions. The concept of rates of reaction and catalysis are discussed here. In addition, heats of reaction and equilibrium are taught in this section. As typical reactions, acid-base reaction and oxidation-reduction including chemical cells are cited. Finally structure of matters is discussed. Electronic configuration is limited to the level of Bohr's model and metallic bonds are excluded.

The contents of biology and earth sciences courses are omitted here because of the limitation of space.

A wide range of electivity of courses according to the interests and talents of students means that colleges must be prepared to accept students of diverse ability and backgrounds. However, Japanese institutions of tertiary education have a privilege that they can ask students to take given courses by giving them entrance examinations. There are institutions which request to take physics and chemistry examinations. Some admit more freedom in entrance examinations than this but ask studnets to be prepared for the lecture or laboratory works which assume that certain levels of training have been given in upper high schools. Thus it is very common, for science students, that the highest possible training in upper high schools is required to succeed in entrance examinations.

Indeed, the lowest number of credits required for the graduation from upper high schools does not mean that all the students take that small number of credits. Traditionally high school students used to take 12 or more credits in science courses. That kind of trends is still popular for students who wish to study further in higher institutions. We may even assume that science students have had 16 credits in science: four out of possible five courses in science are very likely to be studied by those who enter science courses of universities and colleges.

Among universities and colleges, there are three varieties of entrance examinations. The first is the most general-education oriented. They take students as science majors and literature majors. The second selects students by the faculties. Here students must decide whether they are interested in faculty of engineering or in faculty of science in addition to their general interest in science. The third is still more specialized. Departmetns select their own students. In this case, an applicant to a university must decide whether he is interested in department of chemistry or in department of applied chemistry.

Although the students are admitted into the departments in the third case, it is still required that they take general education courses. General education usually lasts one and half years. During this period, the student had been requested to study 36 units of general education courses, 12 units each of literature, social science, and natural science. However, the pressure of professors who wished to give specialized education in earlier ages was very strong. In addition, the student unrest which prevailed in 1968-1970 led the university system to varieties of styles. Thus it is now possible that, if students wish to do so, they can select up to 12 units from one or two of the three categories in general education or from courses of their specialized field: for example, the units may be 6 in literature, 6 in social science, and 24 in natural science, at the extreme.

3. Entrance Examinations of Institutions of Tertiary Education

Japan is a rather new country in the sense of western culture.

The history of her higher education is rather short. In earlier days of modern education, the number of enrollments in universities was quite limited. The society did not need a great number of leaders. Nor many families could send their children to universities. Therefore, university graduates were of limited numbers. There were only seven Imperial Universities before the war including those at Taipei and Seoul, although there were some more federal higher institutions and a limited number of private universities. No wonder, most of the graduates of the old Imperial Universities became leaders of Japan.

After the World War II, the opportunity of education was equalized by the new Constitution. Accordingly many universities and colleges, both federal and private, were founded since then. Local goverments also founded universities. Unfortunately however, Japan has been poor for most of the time after the war and has paid not much attention for improvement of higher institutions. Among those institutions, the old Imperial Universities were rather well equipped because of their history. In addition to this, the facts that almost all the Japanese leaders were educated in the old Imperial Universities allured people to send their children to the famed universities. This trend of course caused very keen competitions for the entrance to famed colleges and universities. Most of the parents in Japan thought that their children ought to receive education in good universities to live better, making the competition in entrance examinations very keen in general.

This trend caused another problem. University professors became to be feared that too many applicants may get full marks if they set easy questions, although they have to give a sequential number to the applicants to allow them to enter the institution up to a given number of seats. Thus the examination questions had become more and more difficult. There was another unfortunate point in the system of entrance examinations. That is the problem of small colleges. There may be only a few chemistry professors in a given institution. Yet they have to give entrance examination questions: they have to make questions every year in addition to marking a vast number of papers. It may naturally be expected that they set questions on the stand point of easier marking rather than that of good questions. This trend has also made the entrance examination unconfortable and time-consuming for the preparation. Here a chicken-egg problem starts: better preparation and harder questions.

These problems, becoming a great social issue, gave tertiary education institutions pressures to modify their entrance examinations. Thus the federation of national universities now cooperate in giving a common examination for the first screening of the candidates. It is officially called the Joint Achievement Test for University Entrance Examination. The system started in 1979. The first idea was to involve every institution, private or public, but in practise there are various problems in private institutions for joining the system. Therefore federal and local-government supported institutions join the system at present together with a few private ones.

The aim of the Joint Achievement Test is to be said that it tests whether a candidate achieved what are expected by the national standard in high schools. The subjects examined are Japanese, English, mathematics, social sciences, and natural sciences. At the present, the test in science is given from the items, which are included in the Course of Study, corresponding to six credits. That means that an applicant must take two subjects in science. Chemistry is fortunately a favorite subject of the applicants. Over 70% of the applicants take chemistry examinations. This is compared to ca. 50% physics, ca. 40% biology and ca. 20% earth sciences.

So far the Joint Achievement Test is favorably accepted by teachers and general public in general. However, it is causing another unexpected trouble. Because the correct answers are publicly announced, students can estimate how high mark they obtained. Then the high-mark students apply to the famed universities but the institutions supposed to be second-ranked are suffering from the fact that only low-class students apply. In the past, even these latter institutions used to receive applications of good students, although the number of them was small. Thus a new attempt is to begin in the coming examination. It is connected to the second entrance examination which is given by a given institution.

A wide variety of second stage entrance examinations is given according to the institutions. At least, however, the results of the Joint Achievement Test are taken into account. Some institutions select students by interview only, some by presenting a short thesis, and some give examinations of all five subjects which are required in the Joint Achievement Test. Evidently, all-round ability is required to get enrolled in institutions where all five subjects are tested. However, increasing number of professors began to think that the all-round talent is not required in a given field. In the coming academic year, the results of the Joint Achievement Test shall be taken into account by multiplying the marks of certain subjects in some institutions. This is considered to be one of the possibilities of avoiding the undesirable trends that the level of students in higher education institutions is controlled by the results of the Joint Achievement Test and new ranking of the institutions takes place.

Private institutions select students by the examination of fewer subjects than the federal or local-government supported institutions. They may be described that the students are specialized in many ways. For example, faculty of literature may not request applicants to take mathematics or science examinations, whereas a faculty of engineering asks applicants to take examinations of science, Japanese, and English.

We must mention the opinions of high school teachers. If a subject is omitted from the entrance examination of universities and colleges, students will not study the subject seriously even though they may attend the class. The all-round education in high schools is thus damaged by selecting certain subjects in entrance examinations. On the stand point of high schools, the more the subjects in the entrance examinations, the better. On the stand point of parents, however, a large number of subjects means that the entrance examinations force students to study beyond their ability. This dilemma may not be solved for ever unless the social situation changes drastically.

4. Unpopularity of Chemistry

Chemistry is very unpopular although many applicants take chemistry in entrance examinations. If department of chemistry selects students by their own examinations, they have to be prepared to adopt students of rather low quality, because there are not many applicants relative to the available seats. The situation is a little better now than some years ago, but it was once possible that there were fewer applicants than the seats. Especially damaged were the departments of polymer chemistry. Some of them abandoned to give independent examinations and now give entrance examinations jointly with other departments.

Other institutions which select students by the faculty have a difficulty in a different way. A faculty of science or a faculty of engineering may be able to select good students because there are popular departments such as electronics, biology and information science. However, at the time when they divide students to departmetns, good students who select chemistry departments are few. As a result, many departments of chemistry suffer from the shortage of students relative to the available seats. Institutions which select students as science majors and literature majors have a difficulty in yet a different way. At the time of division of students, departments of chemistry is usually not affected by the unpopularity of chemistry. They get good students of a large enough number. However, departments of industrial chemistry are a different story. They suffer from the shortage of good students. There can be a possibility that the available seats are not filled.

The reason for the unpopularity of chemistry has been discussed in various ways. However, the last example which clearly shows that pure chemistry is rather popular may mean that the unpopularity of chemistry is connected to pollution problems. Implication of the present status of chemistry is that in order to recover popularity of chemistry, we need a drastic change in the thought of chemical education. We must ask again why we teach chemistry in general education in colleges and universities, since our traditional ways of teaching chemistry have failed to attract many young people.

The traditional way of chemical education is to teach what chemistry is doing and vast amount of knowledge including facts and theories. However, we wish to ask at this moment "is that kind of chemistry really essential for the citizens?" Judges in our country made their decisions on the problems of pollutions and drug hazards. They may get information about facts from specialists. However, final decision is made by themselves. Novelists in Japan wrote influential fictions about chemical pollutions. They can also collect materials which are necessary in writing. But the story is decided by them. What is necessary for politicians for decision making from the stand point of chemistry? It seems to the present author that a really necessary thing for these people is to know the way of thinking in chemistry. We wish to discuss these things in this seminar. If we can get any implication from the seminar that will greatly help us to better the chemical education for the general public including scientists.

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Chemical Education at the General Education Level——An Example

Abstract

Yoshito Takeuchi

(1) Opportunity for Reeducation

Generally speaking, once graduated from his last school, it is rather difficult for anyone to receive an appropriate reeducation, particularly for chemistry, which is good enough to modernize his knowledge. In this respect, the role of tertiary education, and particularly of the general education, is most important since this is the last opportunity for us to teach chemistry to students who are not going to be chemists.

Students belonging to our college (College of General Education, The University of Tokyo) can be classified into three categories.

A: Those who are going to major chemistry or related field such as biochemistry, pharmaceutical sciences, etc. (hereafter chemists-to-be).

B: Those who are going to major physics, mathematics or various fields of engineering and pure sciences (hereafter physicists/engineers-to-be).

C: Arts students

Some of us in this college feel that there are severe problems for each category.

(2) Chemistry for Chemists-to-be

There is no problem as for the attitude of the students is concerned. They are ready to accept chemistry as a means of their future life. The generally accepted idea that the chemistry in the general education is a part of training of chemists-to-be is possibly reconsidered. It might be useful for chemists-to-be to look chemistry from a stand point different from that of a chemist.

(3) Chemistry for Physicists/engineers-to-be

We cannot help feeling that not only they but also we do know that chemistry is not very relevant to their future carieer. Of course it is not difficult to persuade them (and us) chemistry will eventually be relevant to their specialities, but it is difficult to eradicate their hostility toward chemistry.

Some teachers tend to stress the mathematical (theoretical) side of chemistry expecting to demonstrate that chemistry is as good as their favorite physics. My impression is that this is useless if not harmful as a means to attract students to chemistry. Some different approach should be sought.

(4) Chemistry for Arts Student

At our college arts students must choose two sciences among various subjects. Chemistry and biology were most popular among arts students for some time ago.

Recently, some new subjects are added to sciences for arts students in many universities. These are "introduction to natural sciences" and "Sōgō Kōsu (unified course)". The first is more or less introductory history and philosophy of sciences, while the second is rather a new attempt and quite successful in attracting arts students since the lectures are composed of one or two hours talk of various professors in different fields ranging from mathematics to gymnastics and are enjoyable to everyone.

It must be added that the share of chemistry, as indicated by the number of teachers of such new subjects, and by the time spent for chemistry, is gradually decreasing as the new subjects become popular.

I should like to describe what I am doing, more or less isolatedly, as an experiment to recover popularity of chemistry among youngsters.

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CHEMICAL EDUCATION AT THE GENERAL EDUCATION LEVEL

AN EXAMPLE

November 1981

YOSHITO TAKEUCHI

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I OPPORTUNITY FOR REEDUCATION

Generally speaking, once graduated from one's last school, it is rather difficult for him to find opportunity for further education in the field other than his present job. There should not many who would have opportunity to learn chemistry unless he is a chemist. Personally I have not had any opportunity to teach chemistry to those who had already finished schools. In this respect the roll of the tertiary education of chemistry, or of any subject, is very important. For most of the university students, who are not going to be a chemist, two years in the college of general educaiton are indeed the last chance to touch chemistry.

In Japan the system of general education can be very various. In most if not all colleges the destination of freshmen has been determined when they entered the university. In the University of Tokyo, the system is rather unique in that the freshmen are roughly classified into six categories---LI, LII, LIII,SI, SII (F1) and SIII. They spend the first two years in Komaba campus to which I belong, and move to the Hongo campus to spend their third and fourth years. According to the students' wish and their accumulated marks for the first one and half a year, the students are allocated to various departments. There is, however a fairly strict regulation. If one is admitted as a LI student, he is supposed to proceed to the Faculty of Law. A limited number of students is allowd to "convert" their intending major.

At first one tends to think that there is not much chance for choice,but it is by no means the case. For instance a SII student has a wide range of choice--from Faculty of Medicine to Faculty of Letter. This flexibility has caused a considerable effect upon students.

CLASSIFICATION OF STUDENTS There are many number of tests for (F2) chemists. There are four Department of Chemisty, in Faculties of at least Science, Agrigulture, Engineering and Pharmacy. There are several Departments of Biochemistry, too. Hence, there are 380 students for one year who are going to be chemists.

We can classify all the students into three classes.

A---Those who are going to major chemistry or related field such as biochemistry, pharmacy or biology. We shall call them hereafter chemist-to-be.

B---Those who are going to be a scientist or an engineer, but whose major is not chamistry. Those students can be very various. In one extreme, there are mathematicians and in the other extreme, there are veterinary doctors. But for simplicity's sake, we shall call them physicist/engineer--to-be.

C---Arts students I,II and III. They are going to major law, ecomony, literature, etc.

OPPORTUNITY OF TEACHING CHEMISTRY Now, how much chemistry can (F3) we teach to each of these three classes? Students belonging to class A and B are mostly science students. For science students, chemistry, as well as physics and mathematics, is compulsory, and they must finish 4 units of chemistry plus laboratory work for 1 unit. 4 units of chemistry are one lecture per week for one and a half year(three semesters). (F4)

Arts students must choose two subjects out of physics, chemistry, geological sciences, biology,and history of science. Each subject is finished by two lectures per week for one semester. There is no practical for arts students. These are opportunities given for us. Do we use these opportunities very effectively?

II CHEMISTRY FOR CHEMIST-TO-BE

We tend to assume that there is not any serious problem as far as the chemical education for chemist-to-be at colleges of general education in general. It is true that those students are ready to accept chemistry and to absorb whatever we are going to give them.

In certain universities chemistry in junior course is a part of the unified curriculum for chemist-to-be. Lectures for junior course are essentially Phys. Chem. I or Org. Chem. I in the whole curriculum. In other universities such as ours, they teach chemistry more or less independently. Whatever they teach in junior course, lecturers in senior course will start from the very first, i.e., from methane.

A long and hot debate will be affected if the advantage and disadvantage of the two policies are to be compared. I think, however, a policy different from both of the two can be considered for chemistry for chemist-to-be at colleges of general education. When these students advance to the senior study, they will receive a shower of lectures of chemistry, all of which are chemistry for chemists, and chemistry form the viewpoint of chemists.

Such is of course a necessary training for him before starting one's career as a chemist. This means that eventually these students will never realize how chemistry looks like from non-chemists, i.e., citizen's viewpoints. If such as chemistry for citizen ever exists, such should be taught even to chemist-to-be, and this can be done only in junior course.

This should be very ambitious, and be worthwhile to attempt. No attempt has, however, ever been made as far as I know.

III CHEMISTRY FOR PHYSICIST/ENGINEER-TO-BE

To teach chemistry to physicist/engineer-to-be is rather difficult a task because these students are not very ready to accept chemistry. This is particularly the case with students who have some detached feeling to physics or to mathematics. They are in a sense preoccupied to believe that chemistry is inferior to physics and mathematics at least as far as the structure of logic is concerned. At best, they believe that chemistry is totally irrelevant to their future carieer.

Now we are confronted with a difficult question whether we should teach them something which may not be very much relevant to their future carieer. There are several answers for that.

The simplest answer for that question is just to neglect it. We teach them the same chemistry as for chemist-to-be. We might find that most students are very obedient , and readily accept the hard chemistry, i.e., chemistry for chemist-to-be. This does not necessarily mean that they keep to be in good terms with chemistry. Rather, they might have accepted chemistry for the sake of the unit required for finishing the junior course. This is an easy-going solution, and will eventually be very bad for chemistry.

As an another answer for that question, some lecturers seems to have attempted convert these students to chemistry by stressing the theoretical aspect of chemistry in their lectures. These lecturers are generally a little nervous towards somewhat disdainful feeling to chemistry occasionally disclosed by these students. Although I do understand these lecturer's attempts , I do not think the effort is successful.

If the lecturers want to stress some successful application of theoretical chemistry, they must refer to the physical theories which form the basis for the chemical theory, and the students might conclude that chemists have borrowed theories from physicists. The truth is more complicated, and there are always interactions, not one-sided, between physics and chemistry. We should not expect, however, immature students can understand such implications.

I have in mind a different approach. It is by no means clever for chemistry to compete with physics or mathematics in the conpleteness and concreteness of theories. I should rather stress the very complicated and empirical nature of chemical theory. The methodology of chemistry is quite different from that for physics. A comparative study would be helpful to make these students more understandable to chemistry. This point will be discussed in later section.

IV CHEMISTRY FOR ARTS STUDENTS

Arts students are most relevant to the topic of this seminar because they will eventually be "citizens" from chemists' viewpoint.

Previously, we did not have much difficulty as far as teaching chemistry to arts students is concerned. In Japanese university system, arts students are supposed to choose two subjects out of various science subjects. Among them, chemistry and biology have been most popular. These two subjects are basically qualitative as compared with physics or mathematics althoughall the subjects are taught in a qualitative way. But this popularity has not resulted in the respectful attitude to chemistry. They have chosen chemistry simply because it is easy to obtain unit, and because they had learned chemistry at senior high school. Chemistry given in the junior course for arts students have been a kind of extention of senior high school chemistry.

Recently, or for the last ten years, a gradual but steady change has occurred to the curriculum of science for arts students in many universities and colleges. In addition to, or rather, in some universities, instead of traditional subjects, two new subjects have been introduced. One is "Introduction to Science" or "History of Science" and the other is "SÒGÒ KÒSU(unified course)" Fig5

INTRODUCTION TO SCIENCE It is usually a combination of philosophical and historical survey of development of science in general. Our concern is how is chemistry treated in such a subject. This depends as a matter of fact on the philosophy of the lecturers or on the choice of textbook(in many cases textbook written by the lecturers will be chosen). We might, or rather, should expect chemistry should occupy at least a quarter of the pages of the textbook. The situation is very much less than a quarter.

Fig 6

The contents of one typical textbook of introduction to science will be shown. If properly lectured by a good lecturer, the subject should be very stimulating to the mind of junior students ---particularly of arts students. Such a view of science is the very first experience to most of them. Anyway they have never learned such at senior high school. They are now to feel that they really university students. It is quite understandable that if such a subject is open along with the traditional subjects, students tend to choose the former at the expense of the latter.

Since chemistry is treated in most textbooks for introduction to science very briefly, the contribution of chemistry and of chemists(as lecturers) will be diminishing. This is a very serious situation for the chemical world.

The small portion of chemistry in introduction to science is another difficult point to be discussed. The figures are mostly such founders of modern chemistry as Lavoisieur or Dalton. I do not deny the important contribution of those chemists to the establishment of modern chemistry. But students might feel that they have long been familar with their establishments, and that the lectures loose their brilliance whenever something related to chemistry are to be given.

The situation is much the same with history of science. A large number of pages will be spent in Kepler, Galileo, Newton and perhaps Darwin, and a few pages for Lavoisieur and Dalton, but none for other chemists.

F 6

SOGO KOSU(UNIFIED COURSE) Sogo Kosu is an interdiciplinary course which usually covers quite a wide range of topics. Unually a topic and an organizer are chosen by the committee. The organizer sets the framework of the course and choose lecturers from various sources according to this frame. Each lecturer speaks for one or two hours on his favorite work. The organizer will make an opening and a closing remark and explain the aim of that particular course.

Once I was asked to participate into one of Sogo Kosu titled as "Shape or Form". To an organic chemist such as I the word shape is always associated with the molecular shape---tetrahedral methane or chair-form cyclohexane, etc. To an architect or to a mathematician the word should have quite a different meaning.

The structure of this Sōgō Kōsu is given in the separate sheet. It is again evident that the share of chemistry is small---three out of some 25 lectures.

F

Personally I like to participate in Sôgô Kōsu or to lecture introduction to science very much. I should be happier if I am asked to organize a Sōgō Kōsu. If I take, however, the viewpoint of a chemist, I cannot be very happy to notice that the gradual spreading of these new subjects, introduction to science and Sōgō Kōsu is bringing about a serious problem for chemistry.

For the time being, in our university, Sogo Kosu is open only to science students, and further it is optional. Sogo Kosu cannot replace the conventional science subjects such as chemistry. But this is not always the case with other universities. Indeed I know a few colleges where Sōgō Kōsu or equivalent is open to all students and it forms a part of compulsory subjects for arts students. It is highly likely that the new subjects will attract more and more students. What should we do when we find that there are no arts students who choose chemistry as their science subject? I am too pesimistic, but I know something which might materialize my fear.

F7

V HISTORY AND PHILOSOPHY OF SCIENCE

In the University of Tokyo, the College of General Education is basically responsible for junior education. In the Department of Liberal Arts, and in the Department of Pure and Applied Sciences, a limited number of students are receiving their senior education. In the former department, there is a section named as the division of "History and Philosophy of Science". The number of permanent teaching power associated with this section is only four, and the number of students is correspondingly small--five to eight per year.

It must be mentioned that this section has its own graduate school--perhaps the only one graduate school of this kind in Japan. The entrance examination for this graduate school is very hard with many applicants from all over Japan.
The number of graduate students is also limited--two or three per year--but they tend to occupy academic posts which are responsible for science general education, particularly for arts students.

Although it was originally expected that the education in the section of history and philosophy of science should be well balanced among various area of sciences, the fact is that one eventually has to have his main field, e.g., philosophy of physics or history of biology, etc., which is in most cases anything other than chemistry. Consequently, when such one occupies the academic post responsible for junior education of science, he will prepare history of, or introduction to, science and Sogo Kosu for arts students.

For the time being, the number of the graduate of the section of history and philosophy of science is very much limited, and their influence is local. But we have to admit that they are becoming popular and popular.

VI CHEMISTRY FOR CITIZEN

Fig 8

I do not believe that I have a cure-all for the unpopularity of chemistry among citizen, nor a better prescription of chemistry for citizen. I do believe, however, that chemistry for arts students as well as chemistry for physicist/engineer-to-be should be modefied so that the new chemistry can compete with the introduction to, or the history of science, and Sogo Kosu. What I have in mind has the following characteristics.

(i) It describes the development of a limited area(or a topic) of chemistry from mid 19 c. to the present stage.

(ii) The topic should not be very broad. The scope of the topic is as large as of a standard monograph for specialists.

(iii) The chemistry should not be very difficult, but should not be mere extention of senior high school chemistry.

In other words, the attempt is more or less the modern version of Harvard Case History organized by Prof. L. NASH . Indeed, Harvard Case History had a great success when it appeared. The value of this series remained unchanged, but the topics are rather old to most of students. They now have some impression that they are well aware of Lavoisier or Dalton. If we treat topics much modern, students might be impressed and a better effect may be obtained.

I have set up three such attempts, each is just for one semester's lectures. The title of these serial lectures are---

A. A Story of Methylcyclohexane---a story of conformational analysis (abridged version of B.)

B. Lights and Chemists---a story of light as a means to explore molecular structure

C. A Molecule dances....a story of stereodynamics of ring compound.

In these lectures I attempted to describe the characteristic methodology of chemstry in comparison with the other natural sciences.

Once or twice I made an experiment, i.e., I delivered the serial lectures to arts students and students of Department of Liberal Arts(senior students). So far the responce is good. I will continue to blush up the content of the lectures so that not only arts students but also physicist/engineer-to-be will attend the class with satisfaction.

Fig 1

The Structure of the University of Tokyo

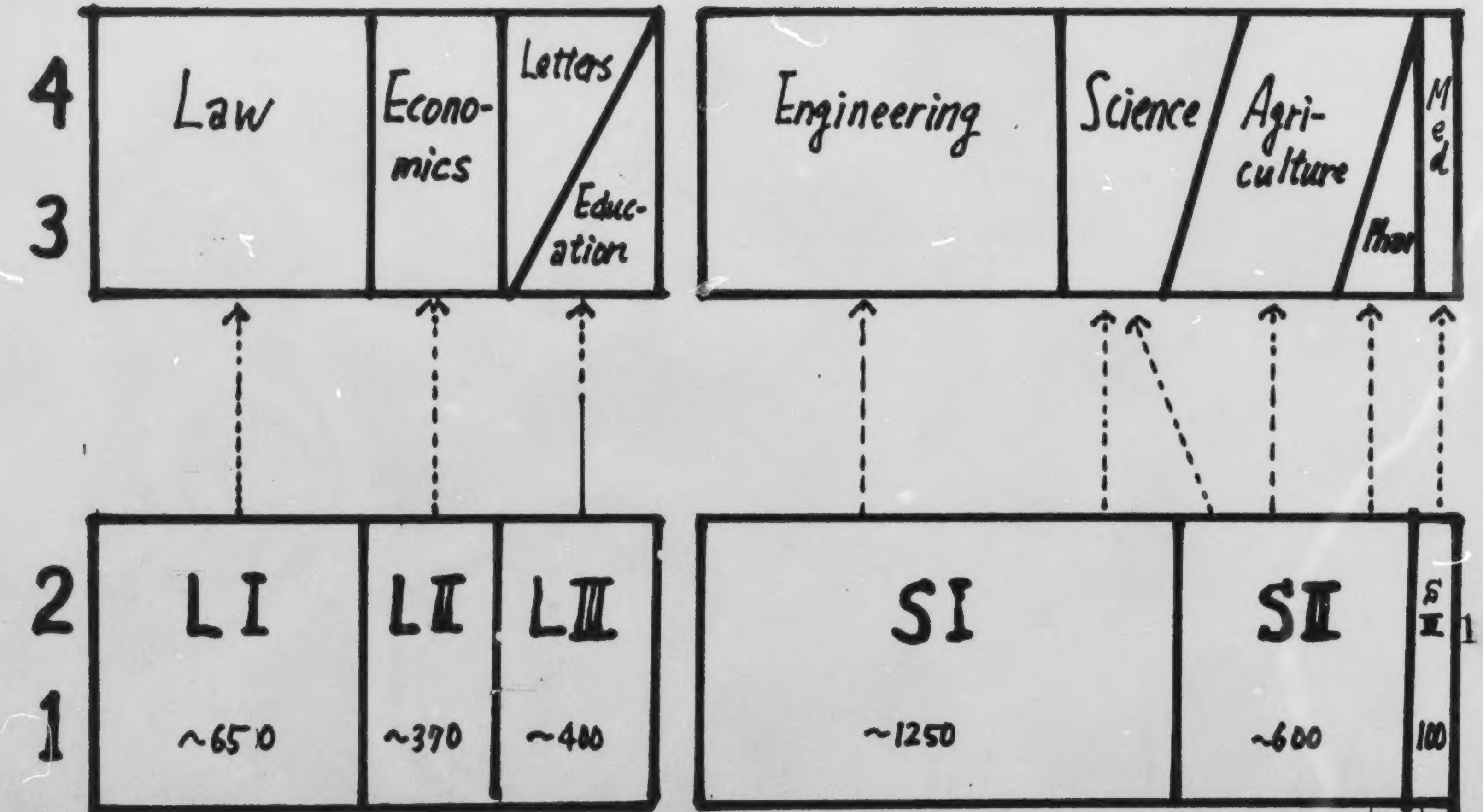
4
3
2
1
Law
Economics
Letters
Education
Engineering
Science
Agriculture
Phar
Med
LI
LII
LIII
SI
SII
SIII
~650
~370
~400
~1250
~600
100

Fig 2

Classification of Students

1) chemist-to-be

→ Faculty of Science, Department of Chemistry (88/2)
→ " , Department of Biophysics & Biochem (44/2)
→ Faculty of Engineering, Dept of Industrial Chem. (95/2)
" , Dept of Synthetic Chem. (69/2)
" . Reaction Chem. (45/2)
" , Chem. Engineering (81/2)
→ Faculty of Agriculture. Dept. of Agricultural Chem. (144/2)
" , (Dept of Fisheries) (42/2)
→ Faculty of Pharmaceutical Sciences
, Dept of Pharmaceutical Sciences } (141/2)
, Dept of Pharmaceutical Technochemistry }
(ca. 50% Biology-oriented)

2) physicist/engineer-to-be

3) arts students

4) special case → College of General Education,
Dept of Liberal Arts * 212/2
Dept of Pure and Applied Sciences 109/2
* History and Philosophy of Science (5~10 per year)

Fig 3

Chemistry Course for SI, SII, SIII

			(90min/lec)
freshmen**	1st term	thermodynamics (chemical)	15 lectures
	2nd term	chemical bond theory	〃
sophomore**	3rd term*	Introductory organic chemistry	〃
	4th term	major education starts	

* (selective)	inorganic chemistry
** (selective)	Sôgô Kôsu (unified course)

Fig 4

Science Subjects for LI, LII, LIII

selective, but two subjects should be taken.

	(90 min/lec)
Mathematics	30 lectures
Physics	"
Chemistry	"
Biology	"
Geological Science	"
History of Science	"
Sōgō Kōsu (unified course)	"

FIG 5

Introduction to Natural Sciences

I History of Science

§1 Outline of History of Science ; Ancient and Modern Times

- A Outline of History of Science
- B Ancient Science
- C Medeaval Science

§2 Development of Modern Science

- A Introduction
- B Rise of Modern Science -- Science Revolution
- C Industrial Revolution and Science
- D Development of Science
- E 2nd Industrial Revolution
- F Development of Science in 20 C

II Nature and Method of Science

§1 Method of Science

- A Purpose of Scientific Research
- B Method of Science
- C Scientific Explanation

§2 Philosophy of Science

- A Ancient idea of Science
- B Philosophy of Science in the Scientific Revolution
- C Philosophy of Science in 18C
- D Philosophy of Science in 19 C and 20C.

Fig 6

Sôgô Kôsu (Unified Course: an example)
"Shape or Form"

1	Shape and Group Theory	2	Mathematician
2	Shape of Differential Equation	2	"
3	"Catastrophy" theory	2	"
4	Form of Physical Law	2	Physicist
5	Shape of Crystals	2	" (Crystalographer)
6	The shape of atoms	1	chemist
7	The shape of molecules	1	"
8	The shape of polymers	1	"
9	Shape of virus	1	Biologist
10	Shape of larvae		"
11	Shape of organs	2	"
12	Methamorphoses of plants	2	"
13	Design of machines and their forms	2	engineer
14	Building — shape and form	2	"
15	Forms of sports	2	physical education specialists.
16	Abnormal forms and shapes	2	"organizer"

FIG 7.

Structure of Komaba Campus

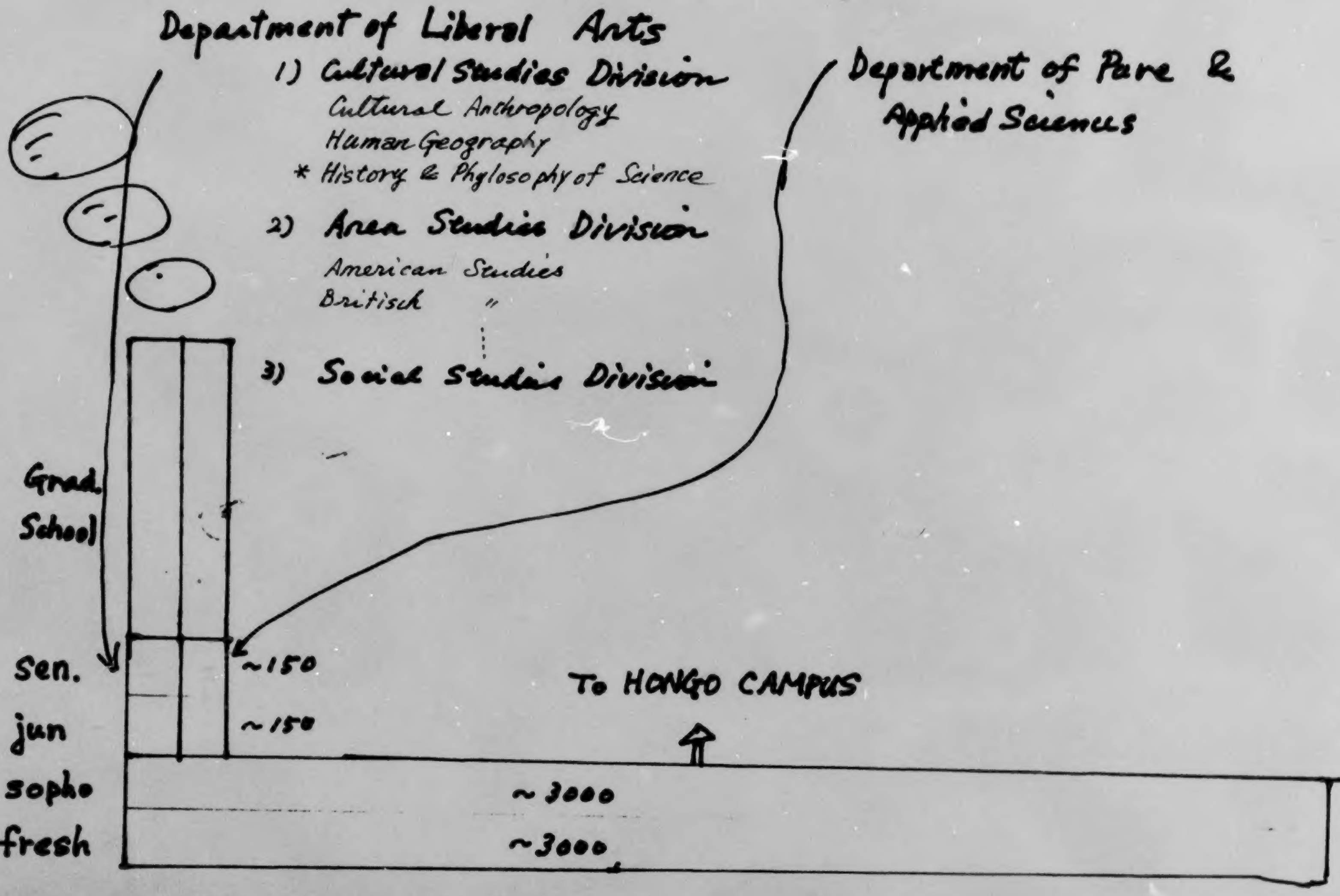
Department of Liberal Arts
1) Cultural Studies Division
Cultural Anthropology
Human Geography
* History & Phylosophy of Science
2) Area Studies Division
American Studies
Britisch "
3) Social Studies Division
Department of Pure & Applied Sciences
Grad. School
sen.
jun
sopho
fresh
~150
~150
~3000
~3000
To HONGO CAMPUS
Senior
Junior

Fig 8

"Chemistry for Citizen" Attempted

1) A Molecules dances

Rise of Atomic-Molecular Theory —— Valence —— Tetrahedral Structure —— Isomerism —— Rotation of Single-bond —— Baeyer's Strain Theory —— Sachse-Mohr Theory —— X-ray study —— Spectroscopy as a means of Structure Determination —— Stereodynamics of molecules —— We look molecules dancing by N.M.R.

2) A Cyclohexane Story (abbridged version of 1)

3) Light and Matter

What is light? —— Early Spectroscopy (Newton - Hershell) —— Bunsen-Kirchhoff —— Helium —— Infrared spectra —— Other spectroscopy

Matter, or what we believe "matter"

= f (theory, method of the time)

-4-

CHEMISTRY FOR NONSCIENCE STUDENTS

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This paper describes a chemistry course for nonscience students. Such a course is offered at the University of Wisconsin-River Falls and at hundreds of other colleges and universities in the United States of America and at many schools in Canada and other countires. By "nonscience student" we mean students with majors in the arts, humanities, and social sciences. This course is not intended for nurses or other health science students, nor for those students in agriculture whose curricula require professional chemistry courses.

Students who major in chemistry (or another science) in the United States are usually required to take courses in the humanities and social sciences as a part of an overall liberal education. Many schools feel that students who major in art, literature, or sociology (for example) should take courses in the sciences as a part of their education. No person can be considered to be educated without some understanding of what science is, how science works, and how science effects their daily lives. Further, it is important that students understand physical laws and gain an ability to apply some of them to their personal problems and to those of society.

How much mathematics can we use? In my experience, I have found it best to use very little. These students can learn to do stoichiometric calculations, but this topic requires too much class time. I would rather have the time to develop other topics. Some areas of enormous importance can be dealt with quite effectively in a qualitative manner.

Following are some examples of physical principles and their application to everyday situations. Some of these are included in my textbook, Chemistry for Changing Times, 3rd edition, Minneapolis: Burgess Publishing Company, 1980.

One of the first principles encountered in a chemistry course is the Law of Conservation of Mass. We can restate it in a variety of ways. Matter is conserved. Atoms are conserved. Since atoms are conserved, how can we get rid of those we don't want -- those substances we call wastes. The simple answer is that we can't. We can dump wastes in the water, on the land, or in the air. Those are the only real alternatives that we have. We can't obliterate atoms, nor can we change atoms from one kind to another -- without an enormous expenditure of energy. We can change the combination of atoms, however. Toxic carbon monoxide can be changed to less harmful carbon dioxide. Mercury metal vapor can be changed to less harmful mercury sulfide. Sometimes nature fools us, though. For years we dumped mercury into the environment, assuming it would end up as insoluble (and thus harmless) mercury sulfide. Then in the 1960s it was discovered that certain bacteria can convert insoluble forms of mercury to methyl mercury, a form even more toxic than the metal itself. We cannot destroy matter, but we can change it from one compound form to another.

Let's look at the question from the other side. If matter is conserved, how can we ever run out of any material? If copper atoms are conserved, how can we ever run out of copper? We won't run out; we will merely scatter copper atoms so widely in the environment that it will be too expensive to gather them again to useful concentrations. We may therefore introduce the idea of entropy as scattering. Scattering is spontaneous. It is easy to pollute. Gathering scattered atoms of gold or copper or phosphorus is difficult; gathering requires an input of energy. Low entropy gold is useful -- as jewelry and electronics and money. High entropy gold -- all those enormous quantities in the waters of the sea -- is useless. To extract a troy ounce of gold from the sea would require an input of energy that would cost more than the $650 or so that the gold sells for.

So the simple -- but powerful -- idea of conservation of matter leads quite naturally to a discussion of recycling, pollution, concentration of ores and minerals, and other interesting topics. And it provides the students with an insight into some of our problems that they get nowhere else in the curriculum.

Another important principle with interesting applications is the Law of Conservation of Energy. If energy is conserved, why do we have an energy crisis? Energy is conserved, all right, but it can be changed from one form to another. In any spontaneous change, the energy winds up in a less useful form. And in every change some of the energy is lost as heat. Again, a simple yet powerful natural law has enormous practical applications. It places considerable constraint on what we can do to "solve the energy crisis." To convert coal to (more convenient) gaseous or liquid fuels requires that we forfeit a part of the energy of the coal. To use electricity to produce hydrogen for use as a fuel requires that we forfeit a part of the electrical energy as waste heat. And we have already surrendered a major part (ca.60%) of the energy of the coal or uranium that we used to generate the electricity. Thus the idea that energy is conserved leads quite naturally to a discussion of the laws of thermodynamics. An understanding of these laws changes forever the way students view "the energy crisis."

Another law of enormous importance is the Law of Constant Composition and some of its corollaries. Water is always H_2O. Water is what it is. Its properties are invariant. Water is always wet. Compounds are defined by their composition and structure. When considering food, food additives, and drugs, this invariance of properties is especially important. A chemical compound -- regardless of where it comes from or how it is made -- has a constant composition, structure, and properties. Vitamin C is ascorbic acid, a chemical compound. Its properties do not depend on its source, advertising claims, or our wishes. Aspirin is acetylsalicylic acid. It has a nice set of desirable properties -- antipyretic, analgesic, anti-inflammatory, and anti-coagulant -- and some that are undesirable -- it promotes bleeding and causes allergic reactions in some people. The desirable and undesirable properties are inseparable. Indeed, the anticoagulant action may be desirable -- it may decrease the chance of a stroke or heart attack -- or undesirable -- promoting bleeding from a would or aggravating an ulcer -- depending on the circumstances. In more basic terms, knowing that one aspirin tablet is the same as another can save the consumer a lot of money.

What about laboratory? Should there be a laboratory for the nonscience students? Laboratories are expensive in a time of tight budgets and demanding of staff time when we teachers already have more than we can do.

All of us have felt those constraints. I believe, now more firmly than ever, that nonscience students should have laboratory experience. I just as firmly believe that the experience should not be the traditional one in which students test laws that are already well-proven, redetermine physical constants which are more easily found in a handbook, and analyze "made-up" unknowns. The main goal should be to get the students involved in investigating the real world. We should use made-up samples only to show what a positive test looks like or to calibrate our apparatus.

The role of chemists in society is changing. Indeed, it must change if chemistry is to survive as a profession. In the past, most chemists have concentrated on making new products -- "better things for better living." While we will continue to need new and improved materials, more and more chemists will have to become involved in designing "better processes for a more livable world." Chemists will also become more involved in monitoring air and water quality, chemical dumps, and other aspects of our chemical environment. It is these changing roles that we should emphasize in the laboratory for nonscience students.

I believe that a chemistry lab for nonscience students should, as far as possible, adhere to four guiding principles. First, the experiments should be short -- one hour if possible, not more than two hours. That makes labs easier to schedule and it is easier to maintain student interest. Second, the experiments should use cheap, everyday materials. Ask students to bring materials from home or buy them at the store. The need for "cheap" is obvious to most of us. Perhaps more importantly, students are more comfortable using familiar materials and more interested in such experiments. Third, we should avoid as many of the more hazardous chemicals as possible. Total avoidance of hazard is impossible. And even if it weren't, it would be unwise. We should try to teach them how to handle dangerous substances safely, a practice that we hope will carry over into their everyday lives. And fourth, we should strive to devise more interesting experiments, yet ones which still illustrate important principles.

A number of experiments, in which we strove to meet these criteria, are included in Scott, Hill, *et al.*, *Chemical Investigations for Changing Times*, 3rd edition, Minneapolis: Burgess Publishing Company, 1980.

This is but a brief description of a chemistry course for nonscience students. Chemical principles can be applied in the daily lives of all citizens. Chemistry is important to everyone. That they know some chemistry -- and that they know that knowledge of chemistry is useful -- is important to us as scientists and teachers. Our countries need citizens who are better informed, more interested in science, and more supportive of science, especially of basic research. As teachers, we have accomplished a great deal if we can convince our students that the world, for all its bewildering complexity, is comprehensible and is potentially subject to the control of the human mind. Knowledge gives power, and chemistry is an important way to gain knowledge about the world in which we live.

A Two-Semester Course for Non-Majors

Many U.S. institutions of higher education require at least one-year of science for non-science majors. This may be satisfied by (at least) a one-year course in one of the sciences or, alternatively, by two (or more)semesters in several sciences. The appropriateness of formulating a chemistry course designed especially for these persons should therefore be obvious, but unfortunately, many institutions have not done this. Most students in most universities are not science majors and it seems logical to develop appropriate courses in science designed for these students. Having a second term in such a course would be most desirable in the view of many persons because it would allow flexibility with regard to the inclusion of topics and experiments that could not be included if only one semester is available for such a course.

A. Topics Which Might be Included in a Two-Semester Course Include:

1. The energy problem, including the chemistry (and problems caused by this chemistry) of the utilization of coal, nuclear materials, petroleum, the sun (including hydro, wind, ocean thermal differences), waves, etc.
2. Pollution problems, including air and water pollution, hazardous wastes and their disposal, etc.
3. Food production and many of the chemical problems associated with this.
4. Polymers - their formulation, manufacture, and use.
5. Industrial chemical processes, including the manufacture of both heavy and fine chemicals - the processes by which these are made.
6. Medicinals and drugs - their formulation, manufacture, chemistry, and problems associated with their use. Organic and biochemistry, including important biological cycles, vitamins, hormones, enzymes, proteins, genes and their modification, etc.

Topic 15 (continued)

7. Nuclear chemistry and the fundamental composition of matter, fission, fusion, and other important radiological processes.

8. Electricity and its use in chemistry and chemical processes.

B. Among Laboratory Experiments Which Could be Introduced in a Two-Term Course are Included:

1. Quantitative chemistry, including titration.
2. The determination of water hardness.
3. Electrolytic and voltaic cells.
4. The synthesis of important and interesting organic substances, such as aspirin and important esters.
5. Osmosis and dialysis and their application to human life, including kidney dialysis.
6. The synthesis of nylon.
7. Pesticides, herbicides, insecticides, etc.
8. Polymers.
9. Colloidal systems.
10. Corrosion and its inhibition.
11. Analysis of important substances (e.g., milk).
12. Experiments involving the use of simple, but important equipment, e.g., spectrophotometers, pH meters, microcomputers

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Wayne State University

-6-

POSITION PAPER

What changes in distribution of materials would be desirable if a two-semester (or term) course were to be taught for a non-major student?

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First, I would examine the topics for the one-semester (or term) course to determine if some of these should be explored in greater depth and if additional experiments could be done that improve the interest and learning in the course. Then I would choose topics that had not been possible to include in the one-term course to extend the understanding. For example, I think these students need an introduction to biochemistry and I'd place it very high on the list of materials to be included. Through biochemistry, a number of important principles learned earlier can be consolidated and extended. They include catalysis, principles related to types of reactions, rates of reactions, complexities of reactions, and chemistry related to the student as a human being. This would require more attention to organic chemistry which could also be used to give students an introduction to and some understanding of petroleum chemistry, pharmaceutical chemistry, polymer chemistry (essentially areas of importance in our economic growth). If time were still available, I would choose topics from environmental chemistry to help students understand weathering, erosion, pollution, fertilization, etc. If still further time remained it would be attractive to add content on collodial chemistry, on photochemistry,on nuclear processes to broaden the students' perspective and view of their own world as well as that of the entire chemical enterprise.

- 7-

The Nature of Science Education: Implications for Communication Media

J. J. Lagowski

Most modern sciences are dynamic subjects, undergoing constant change in content. Many scientific principles may be well-organized and understood, but the training of scientists suggests it would be a serious error to assume that the present collection of principles will remain static in the future. History shows us that the changes in the content of most sciences are neither smooth nor necessarily foreseeable. Thus when we "do" or teach science, we must deal with an unpredictable dynamism, which is the root of the problem of educating scientists, as well as non-scientists.

Those who would attempt to communicate "science to the masses" have to make a fundamental decision--whether to discuss results or to attempt to include ideas which involve the processes of science. The former can often be done superficially with relatively little need for specialized training--a press release, a little research, and a reasonably glib way with words. The latter requires a deeper insight into the processes by which value judgments in science are made, as well as a willingness to attempt to pick through tedious details; it also requires care and an extraordinary skill in the presentation of the subject or the final piece will reflect the tedious detail and hence not be effective with the intended audience.

If academic scientists are to affect mass media communicators, they must devise methods of presenting the essence of the processes of science in a non-trivial way (not leave it to the phrase "the scientific method") to potential science writers, as well as techniques for the continuing education of science writers.

Position Paper

Goals of Science Education

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All education is an enabling process. A course provides the environment in which a student is enabled to make progress toward accomplishing something. These processes of accomplishing somethings are the goals.

A limited list of goals for chemical education follows.

I. To participate effectively in the social, economic and political process of our pluralistic society.

II. To become a chemist and to continuously enhance one's professional competence as a chemist.

III. To become a scientist other than a chemist and to continuously enhance one's capabilities as a scientist.

IV. To attain and to continuously enhance one's professional competence in a field other than a science.

V. To become and continuously develop one's effectiveness as a communicator, as a leader in the formation of public opinion and as a decision maker.

VI. To enhance and continuously strengthen one's self-image as an individual who understands the processes of physical, chemical and biological change.

Goal I is a societal goal for all students and is a goal that scientists must honor in the development of educational programs in the sciences regardless of the professional goals of the students.

Goals II and III have been traditionally the focus of the scientific community and are essential to the future vitality of science and technology. These goals and the educational programs developed to achieve them are not in question at this conference.

Goal IV is a goal which is just beginning to be recognized as a developing and increasingly significant responsibility of the scientific community. An understanding of the processes of science and technology, including an understanding of the powers and limitations of science and technology, are increasingly relevant to professions such as law, business and journalism. The tools of these professions are increasingly based in technology and the substance of their concerns are also increasingly technical.

Goal V is again a societal goal and must be a primary concern of the scientific community in the structuring of educational programs.

The welfare of our technological society is dependent upon effective leadership in matters involving science and technology and that includes a vast array of social, economic and political matters.

Goal VI is a humanitarian goal. I consider it of great significance to the well-being of the individual. To the degree that an individual lacks confidence to learn and enjoy scientific matters that individual is in part destroyed. It is my experience that to argue from this goal for curriculum developments is remarkably ineffective.

This seminar is primarily concerned with the strategies at the tertiary level in pursuit of Goals I, IV, V and VI. To me, this translates into three types of courses:

A Introductory courses for students who do not need to develop technical competence to achieve professional goals,

B Introductory courses for students who need to develop limited technical competence in limited areas of science to achieve professional goals, i.e. agriculture students, and

C Upper level courses for students in professions that involve the utilization or control of science and technology, i.e. law, business and journalism.

I judge that the mission of this seminar is to address type A courses but I hope we also give some consideration to sequencing types A and C. The comments that follow will address type A, introductory courses for students who do not need to develop technical competence to achieve professional goals. Such a course or courses may be a student's primary route to Goals I and VI and the foundation for Goals IV and V.

What does one hope the student can achieve through such a course? My goals for such a course are to provide the environment through which the student

a) discovers that he or she can understand matters scientific and the processes by which scientific knowledge is acquired,

b) discovers that he or she enjoys the process of extending his or her knowledge, and

c) discovers that he or she can extend his or her knowledge (at least) at the level of the mass media, and

d) continues to extend his or her knowledge at the level of the mass media for the next half century.

It is worth pointing out that some of the above do not lend themselves to testing and that none of the above specifies the systems that should constitute the framework of the course. I am convinced that an almost unlimited number of courses could be developed to provide the environment for the student to achieve the four goals specified above (a through d). I am also convinced that unless the student achieves the goals, both the institution and the student have made a poor investment.

In the design of the course, systems and principles should be selected and orchestrated to produce an integrated whole. This cannot be achieved by starting with an introductory course designed for majors or a course derived from an introductory course designed for majors, and deleting topics. In fact, the process is quite the opposite. Decide where you want to end and introduce that which you need to get there. I have done this more or less successfully using the exploration of the properties and structures of polymers as the goal. To get there you need quite a bit of chemistry and the route not only makes it possible but almost requires that many concepts become recurring themes.

The choice of systems and concepts that provide the apparent structure of the course is related to the mechanism that is attractive in achieving Goal VI. I believe that students are attracted to phenomena and that they enjoy an approach to chemistry through phenomena leading to a desire for correlations, rationalizations and models. You have to be realistic about what can be accomplished in one semester.

As a profession, we have yet to use our creative talents to develop meaningful first courses for students who do not require technical competence to achieve their professional goals.

-9-

Chemical Thinking and Mathematical Thinking

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Abstract

It is generally thought that chemistry has been developing in the natural science by keeping its distance from mathematics as far as possible. It is true in one sense, but it does not mean that chemistry is neither logical nor mathemtical. There are two different ways for the logical thinking, i.e., deduction and induction. If one classifies every field of natural science into these two categories, mathematics will be the most deductive, and chemistry will be, if not the most, rather inductive. However, we also know that even mathematics has been developing through the repeated chains of deduction and induction.

In my lecture I will stress that there are several common features among the chemical and mathematical thinking and that chemistry has contributed to the construction of some other fields of natural science through its mathematical aspects. The discovery of the law of periodicity of elements induced the modern atomic structure theory, the enumeration problems of alkanes and their derivatives triggered the development of the graph theory and combinatorial theory in mathematics, and so on.

It is our duty to let those chemistry-non-major people know that the way of thinking which chemists have used to construct the modern chemistry is not different greatly from what the mathematics and physics people do. Chemists just prefer to play in the diversity or peculiarity rather than in the simplicity or uniformity of the nature. Chemists are responsible for drawing the future plan of the mankind by supplying the whole knowledge of ten million species of chemical substances which have been and will be produced through the chemical logic or chemical thinking.

Chemical Thinking and Mathematical Thinking

——Interaction through Structural Formula——

Haruo Hosoya

Department of Chemistry, Ochanomizu University, Tokyo, Japan

It is generally thought that chemistry has been developing in the natural sceince by keeping its distance from mathematics as far as possible. It is true in one sense, but it does not mean that chemistry is neither logical nor mathematical. There are two different ways for the logical thinking, i.e., deduction and induction. If one classifies every field of natural science into these two categories, mathematics will be the most deductive, and chemistry will be, if not the most, rather inductive.

However, we also know that even mathematics has been developing through the repeated chains of deduction and induction. There are several common features among the chemical and mathematical thinking, and chemistry has even contributed to the construction of some other fields of mathematical science through its mathematical aspects. Let us first make a brief survey of the history of chemistry where and how chemistry needed the mathematical way of thinking. Some of these problems are found to be tractable more easily if one uses a little more elaborated mathematical tool. In some cases a number of different mathematical methods are found to be entangled. Above all the largest overlap between the chemical and mathematical thinkings might be observed in the problems where structural formulae play a key role. With these examples let us consider the present status of chemistry among and the future role in the natural science and the citizens.

Historical Background

The birth of the modern chemistry is attributed to the discovery of the law of conservation of mass by Lavoisier in the end of 18th century. This is nothing else but the declaration by the chemists that chemistry is a branch of natural science built up from the logical reasoning based on the results of quantitative experiments. Almost at the same time Richter introduced the concept and guiding principle of the chemical stoichiometry. It did not take too much time for Avogadro to assume the existence of molecules as the smallest units of chemical substances, preceded by the discovery of the law of definite proportion by Proust, the discovery of the law of gaseous reaction by Gay-Lusaac, and the proposition of the atomic theory by Dalton.

All the work of these pioneering chemists was the struggle with the inaccurate and insufficient experimental data to squeeze the very essence of the discrete and hierarchical structure of the nature, i.e., atom, molecule, and substance. These developments were made through the repeated chains of deduction and induction just as the mathematics people do.

The 19th century was the age for the chemists such that the topological structure of chemical substances was gradually given light on through the effort by many distinguished chemists, i.e., Liebig, Kekulé, Frankland, Kolbe, van't Hoff, Le Bel, Fischer, etc. Their effort may be symbolized by the isomeric cyanic acid and fulminic acid, the Kekulé structure of benzene, and the projected structural formula of saccharic acid by Fischer (See Fig. 1).

In some sense the concepts of the valency and structural formula are the most chemical products that these chemists have born. However, this is one of the most mathematical tools that chemists have produced. A chemical bond in a molecule marked with a bar or a set of bars can never be observed by any of the modern physical techniques. It is just a symbol produced from the abstracting thinking of the nature. It is not widely known even by a majority of chemists that the isomer enumeration problem led the mathematician Pólya to the construction of the graph theory and combinatorial theory in their modern forms. This will be explained later in more detail.

Another important finding by the chemists in 19th century is the Mendeleev's periodic law of chemical elements. This is a typical example of the product of inductive thinking in chemistry, but led the ambitious physicists in the early 20th century to the quantum theory of atoms and molecules. Once the quantum theory was born, a number of crucial chemical substances were provided by chemists not only for testing the various theorems but also for giving a chance for discovering a new theory. The theory of the representation of the group theory was developed by the joint work of chemists and physicists for interpreting the atomic and molecular spectra in various energy ranges. Numerical analysis especially on the matrix transformation and design of practical computer systems of information processing and retrieval have been established by the contribution of chemists, but these topics will not be discussed further in this paper.

Structural Isomers

In the most primitive but essential sense the structural formula is meant by the topological or adjacency relationship of atoms in a molecule. For example, the four butanol isomers can be predicted by the structural formulae as in Fig. 2a, which, however, not only needs tedious labor to draw but also is mistakable. Then chemists prefer to use the rational formula (Fig. 2b), but it does not give us a perspective view of the skeletal structure of the molecule. On the other hand, graph-theoreticians like to expand these carbon atom skeletons as in Fig. 2c-e, i.e., matchwood, rooted tree, and rooted spanning tree representations. The most concise expression is proposed by a chemist, Wiswesser, as in Fig. 2f. The so-called WLN representations are shown to be unique but not so neat as mathematicians prefer to use. This difference might come from that of the attitude toward the objects concerned. Namely, chemists are obliged to give a useful and unambiguous name to each molecule, while mathematicians need no name for each graph if a unique representation is given. The most mathematical representation might be the adjacency matrix, e.g., for n-butan-1-ol as

$$\begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix},$$

where the lowest diagonal element is tentatively assigned as 1 for a heteroatom. For the purpose of naming and retrieval another algebraic representation as

$$\det \begin{pmatrix} C & 1 & 0 & 0 & 0 \\ 1 & C & 1 & 0 & 0 \\ 0 & 1 & C & 1 & 0 \\ 0 & 0 & 1 & C & 1 \\ 0 & 0 & 0 & 1 & O \end{pmatrix} = C^4O - C^3 - 3C^2O + 2C + O$$

was proposed by a chemist, Spialter$^{1)}$, but is thought to be impractical.

A matrix or determinant expression for a given graph has an important mathematical meaning in the sense that a geometrical object can be transformed into an algebraic representation, and vice versa. In 1937 Pólya, a mathematician, proposed the concept of a counting polynomial which can predict the number of the structural isomers of molecules.2) According to his theory, the number of the isomers of the acyclic saturated alcohols with n carbon atoms is read from the coefficient a_n to the term x^n of the following polynomial,

$$A(x) = 1 + x + x^2 + 2x^3 + 4x^4 + 8x^5 + 17x^6 + 39x^7 + \cdots.$$

This polynomial is obtained from the following recursion formula,

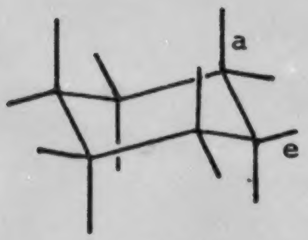
$$A(x) = 1 + \frac{x}{6}[\{A(x)\}^3 + 3A(x)A(x^2) + 2A(x^3)] ,$$

derived from a sophisticated but ingeneous manipulation of the permutation group. Further, the counting polynomial for the number of the isomers of alkanes can be obtained from A(x) as

$$C(x) = 1 + x + x^2 + x^3 + 2x^4 + 3x^5 + 5x^6 + 9x^7 + \cdots.$$

It will be an impressive exercise for both chemistry-major and non-major students to follow the magnificient mathematical structure of the proof of this enumeration problem.3) They will surely realize both the formal simplicity of the structural formula and its mathematical depth.

By the use of the concept of the counting polynomial, the graph theory and combinatorial theory could grow up to what they are today. The next example also shows the powerfulness of the counting polynomial. All the chlorine atoms of benzene-hexachloride (BHC) attach to different carbon atoms and the carbon atom skeleton is the same as that of the chair form of cyclohexane.



Let the upper and lower chlorine atoms with respect to the carbon atom skeleton be represented respectively by open and closed circles. The equatorial C-Cl bonds are marked with a bar, wheras the axial chlorine atoms are drawn on the corners of the hexagon. All the sixteen possible conformations of BHC can then be represented as in Fig. 3.[4] According to the Polyá's theory, this number can be obtained from the cycle index for the point group D_{3d} by purely algebraic manner as

$$\frac{1}{6}\{(e+a)^6 + 2(e^3+a^3)^2 + 3(e^2+a^2)^3\}$$

$$= e^6 + e^5a + 4e^4a^2 + 4e^3a^3 + 4e^2a^4 + ea^5 + a^6.$$

For example the term $4e^4a^2$ stands for the four conformations c–f. However, experiments show that the two chair forms of cyclohexane skeleton cannot be distinguished because of its rapid inversion, and effectively this molecular skeleton is thought to take a planar D_{6h} structure (See Fig. 4). That is the three couples of the conformers facing toward the counterpart beyond the dashed line cannot be distinguished experimentally. This result is also obtained algebraically as

$$\frac{1}{12}\{(e+a)^6 + 2(e^3+a^3)^2 + 4(e^2+a^2)^3 + 3(e+a)^2(e^2+a^2)^2 + 2(e^6+a^6)\}$$

$$= e^6 + e^5a + 3e^4a^2 + 3e^3a^3 + 3e^2a^4 + ea^5 + a^6.$$

Similar discussions can be extended along this line for any symmetrical features of the molecules.

Optical Isomers

Van't Hoff and Le Bel independently proposed the regular tetrahedral structure around the quaternary carbon atom and the existence of the optical isomers in order to explain the optical activity of the substances such as lactic acid. The concepts of the asymmetric atom, optical antipode, and recemic compound were also established by them. These conclusions were obtained from purely mathematical reasoning but not from the physical analysis of the mechanism of the optical activity of molecules.

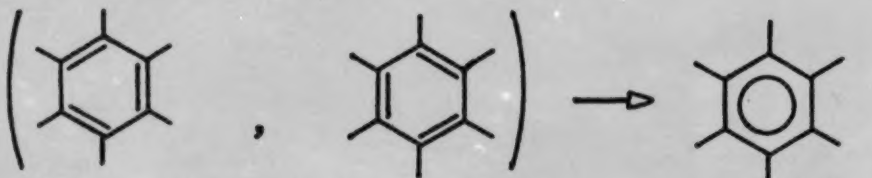
Later Fischer proposed to draw the projection formula for representing the steric structure of molecules with more than one asymmetric carbon atoms (See Fig. 5). Chemical knowledge at his time could not tell which of the projection formulae corresponds to which of the optical antipodes, and thus there were left with two choices which are mathematically equivalent but chemically different. Fortunately, however, Fischer's choice was shown to be correct by the modern physical experimantal techniques. Thus the concept of the configuration around the asymmetric atom was set forth. The flow of logic that Fischer used to deduce the possible configurations of various monosaccharides and the related compounds is purely mathematical.

Resonance Structures

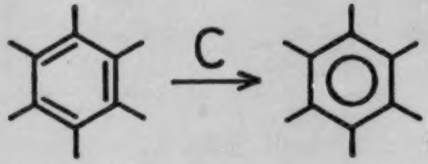
Kekulé proposed the two structural formulae for benzene so as to satisfy the tetra-valency of carbon atoms, and he knew nothing about the quantum chemical concept of the resonance. The concept of the aromatic sextet proposed by Clar was obtained just from the chemical intuition which is based on a huge amount of experimental facts about the benzenoid hydrocarbons. The so-called resonance theory which manipulates the electronic structural formulae by the use of dots and arrows was empirically derived by several brave organic chemists, such as Robinson, Ingold, and Wheland.

Recently the present author found that all the success of the resonance theory is due to the fact that the Kekulé's structural formula has a profound mathematical properties.$^{5)}$

Consider a condensed polycyclic aromatic hydrocarbon, whose skeletal graph G is called a polyhex. The number of the Kekulé structures (hereafter called as Kekulé patterns) for G is denoted by K(G). Let us call the sets of three double bonds circularly arranged in a given hexagon as shown below, respectively, as the proper and improper sextets, whose couple, according to Clar,[6)] forms an aromatic sextet.



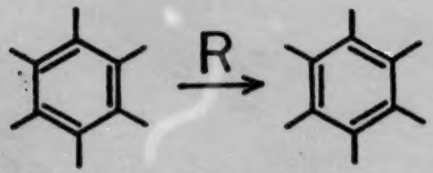
Define the Clar transformation (C) as a simultaneous substitution of all the proper sextets by circles in the corresponding hexagons in a given Kekulé pattern followed by the transformation of the remaining double bonds into single bonds as exemplified in Fig. 6 for the graph corresponding to 1,2-benzanthracene.



Clar transformation

Application of the Clar's transformation to the set of seven Kekulé patterns gives another set of seven distinct patterns including a pattern (s_7) with no sextet. Let the resultant patterns be called sextet patterns. As will be clear from the one-to-one correspondence between the sets of Kekulé patterns and sextet patterns, more than two disjoint aromatic sextets can be resonant if all of them are simultaneously derived from one or more Kekulé patterns.

Next define the sextet rotation (R) as a simultaneous rotation of all the proper sextets in a given Kekulé pattern into the improper sextets



sextet rotation

Application of the sextet rotation to the Kekulé pattern k_1 in Fig. 6 gives another pattern k_7. This process can symbolically written as

$$R(k_1) = k_7.$$

The result of the whole transformation of the set of the Kekulé patterns gives a hierarchical rooted tree graph whose points correspond to the individual Kekulé patterns and whose directed lines to the functional relations with respect to R (See Fig. 7).

It is clear from these two mathematical transformations that the set of the Kekulé patterns for polyhex graphs which have been familiar to the chemists since Kekulé's proposal have important and meaningful mathematical properties. A number of empirical rules for the chemical properties of the aromatic hydrocarbons can be explained by the analysis of these mathematical properties.

Conclusion

One can extend these lines of consideration to the various mathematical features of the structural formulae and get a perspective view of the chemical substances and also the chemical logic. It is also to be noted here that several important relations have been obtained between the results of the Hückel molecular orbital and valence bond methods.[7)] The frontier electron theory by Fukui and the Woodward-Hoffmann rule can tell the mechanistic local information on the reacting species by the use of the symmetry properties of the simplest molecular orbitals. Their work is an outcome of the successful encounter of chemical and mathematical thinking. Although we have made only a rough sketch of the close interaction between chemistry and mathematics, a number of similar problems can be and will be found.

It is our task to let the chemistry-non-major people know that the way of thinking which chemists have used to construct the modern chemistry is not different greatly from what the mathematicians and physicists do. Chemists just prefer to play in the diversity or peculiarity rather than in the simplicity of the nature. Chemists are responsible for drawing the future plan of the mankind by supplying the whole knowledge of ten million species of chemical substances which have been and will be produced through the chemical logic and chemical thinking.

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2) G. Pólya, Acta Math., 68, 145 (1938).

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Figure Captions

Fig. 1 Three typical examples of the structural formula which can express the important topological characteristics of molecules as of the end of 19th century.

Fig. 2 Various representations of the butanol isomers.
a) structural formula, b) rational formula,
c) matchwood representation, d) rooted tree representation, e) rooted spanning tree representation,
f) WLN notation.

Fig. 3 Sixteen possible conformations of BHC as assumed to take D_{3d} symmetry. Three couples of conformers c-d, c'-d', and h-h' cannot be distinguished if rapid inversion takes place.

Fig. 4 Inversion of the cyclohexane skeleton giving effectively D_{6h} symmetry.

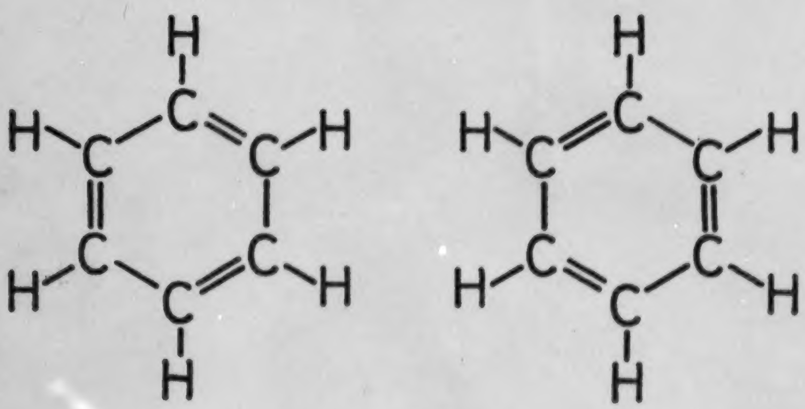
Fig. 5 Fischer's projection formulae for the compound with two asymmetric carbon atoms.

Fig. 6 One-to-one correspondence between the sets of the Kekulé and sextet patterns through the Clar trans formation.

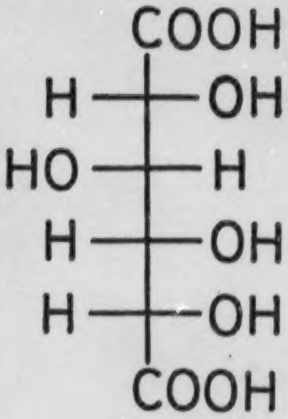
Fig. 7 Hierarchical rooted tree of the Kekulé patterns. The numbers refer to those in Fig. 6.

HOCN cyanic acid

HONC fulminic acid



benzene



D-glucosaccharic acid

Fig. 1

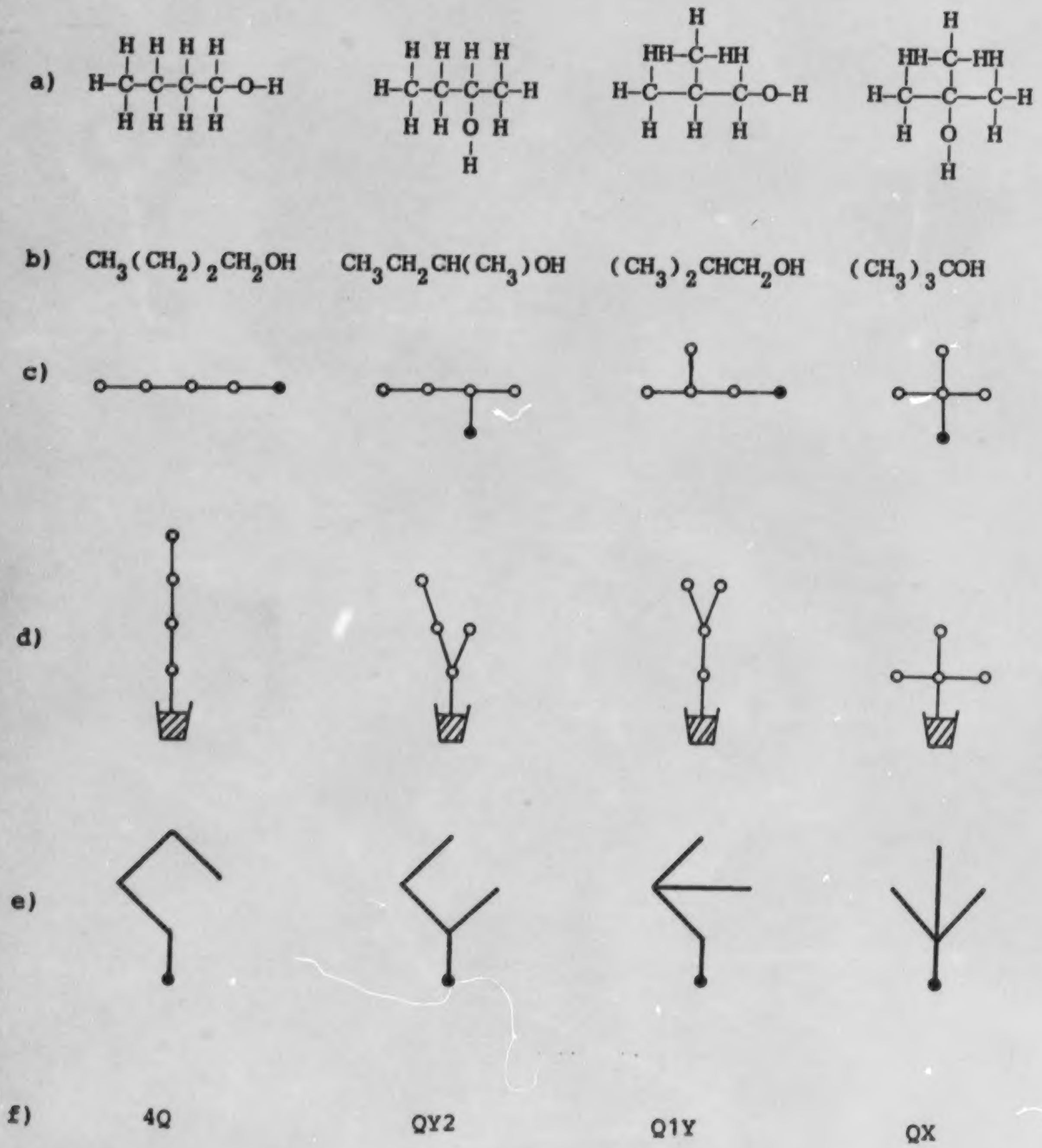
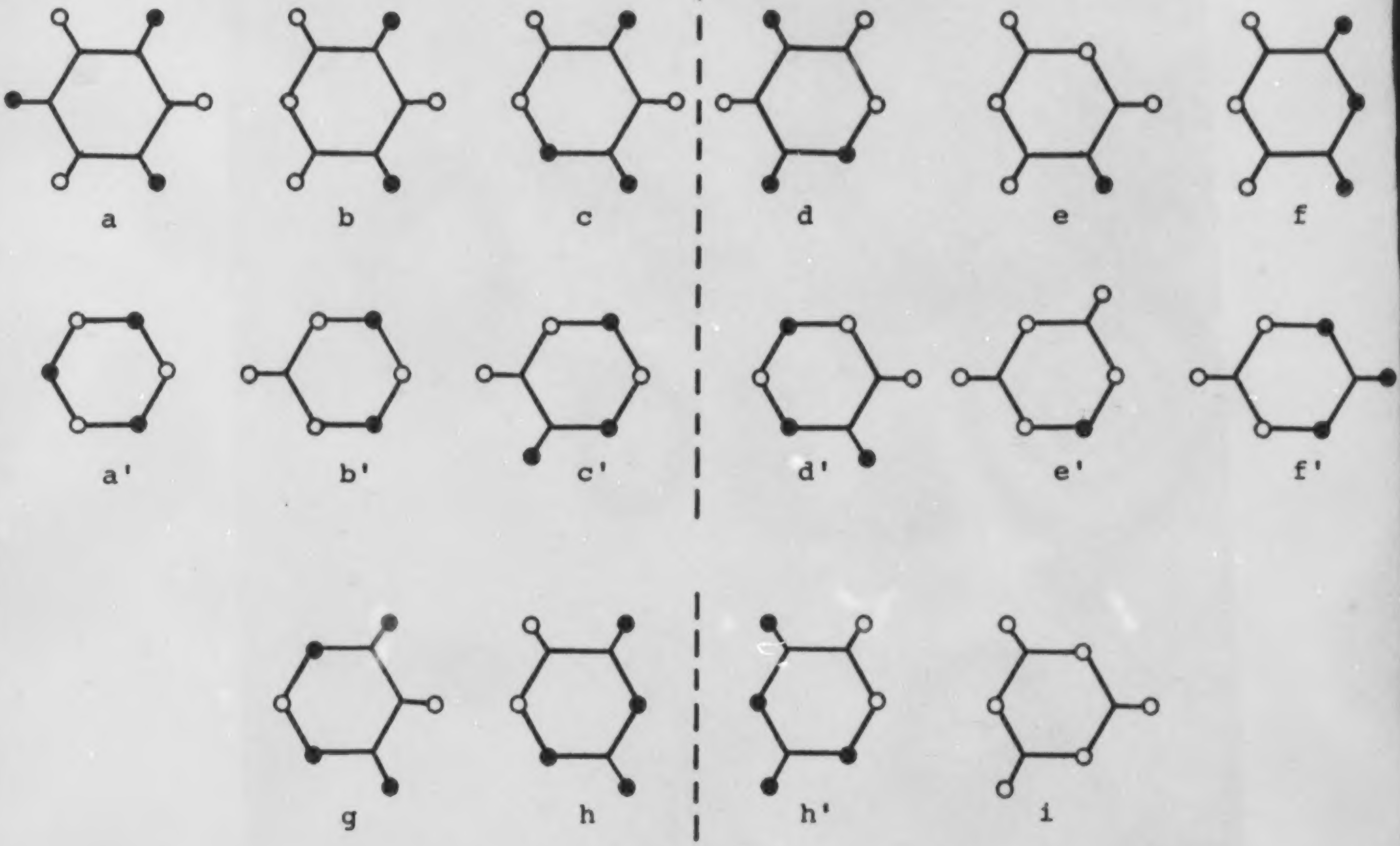
a)
b)
$CH_3(CH_2)_2CH_2OH$
$CH_3CH_2CH(CH_3)OH$
$(CH_3)_2CHCH_2OH$
$(CH_3)_3COH$
c)
d)
e)
f)
4Q
QY2
Q1Y
QX

Fig. 2


a
b
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g
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h'
i

Fig. 3

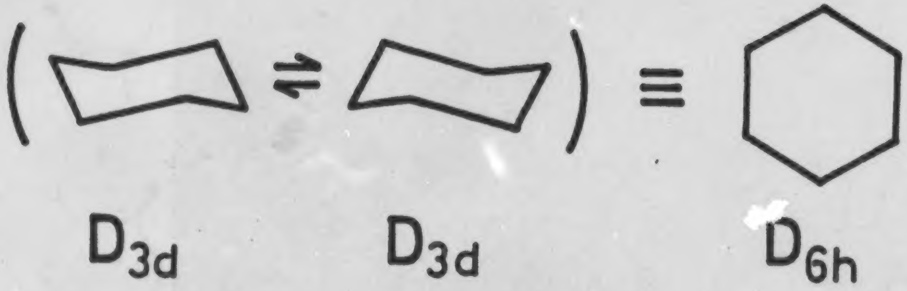
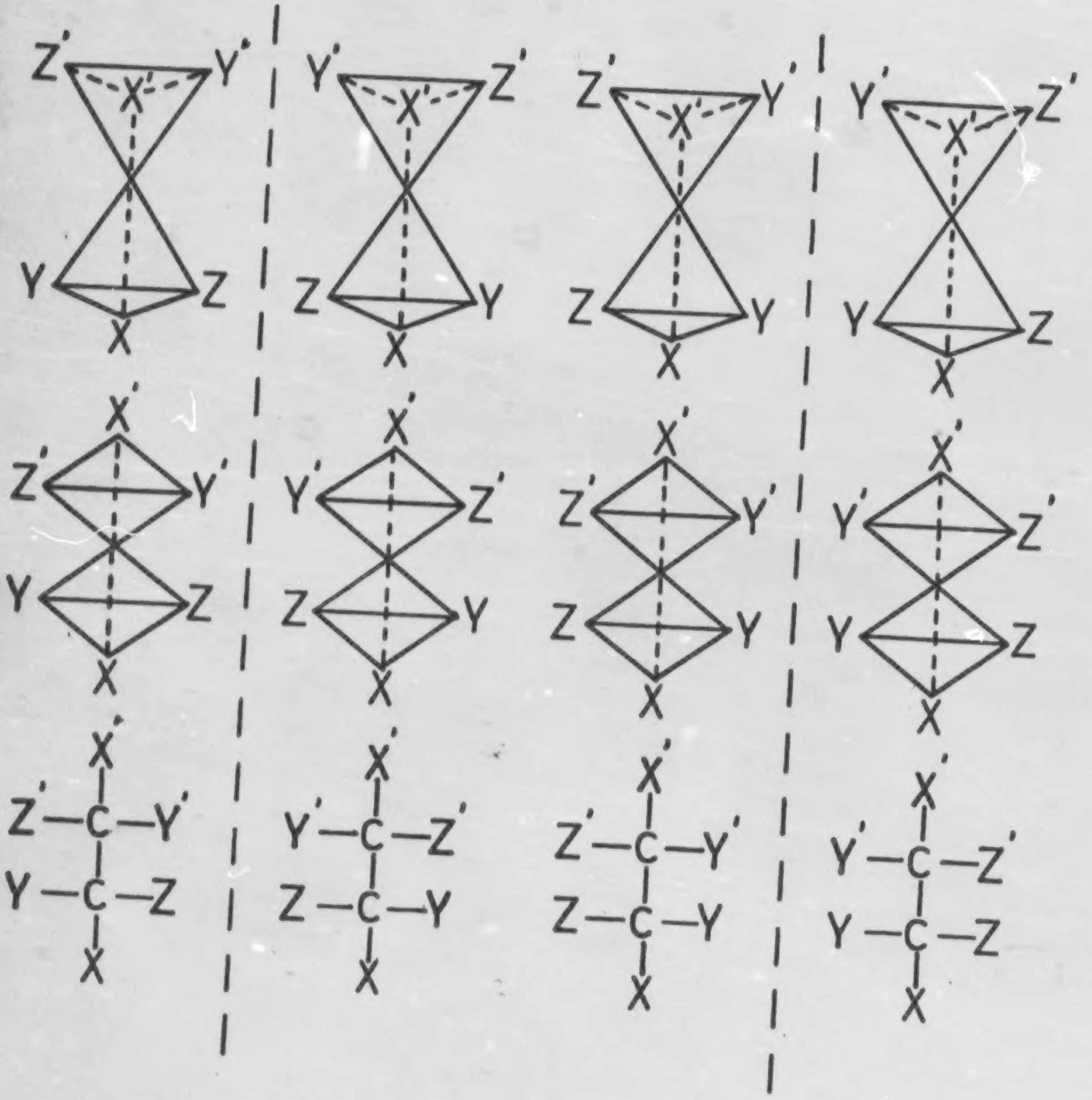


Fig. 4


Z' Y' X'
Y Z X
Y' Z' X'
Z Y X
Z' Y' X'
Z Y X
Y' Z' X'
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Y'—C—Z'
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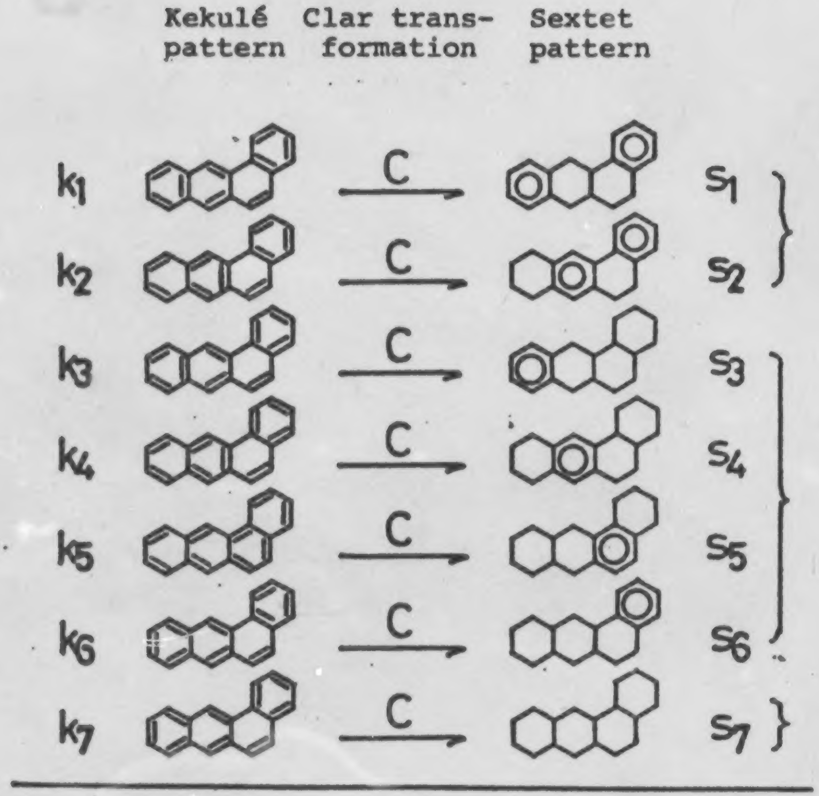
Y—C—Z
X

Fig. 5


Kekulé pattern
Clar transformation
Sextet pattern
k1
k2
k3
k4
k5
k6
k7
C
s1
s2
s3
s4
s5
s6
s7

$$K(G) = |\{k_i\}| = |\{s_i\}|$$

Fig. 6

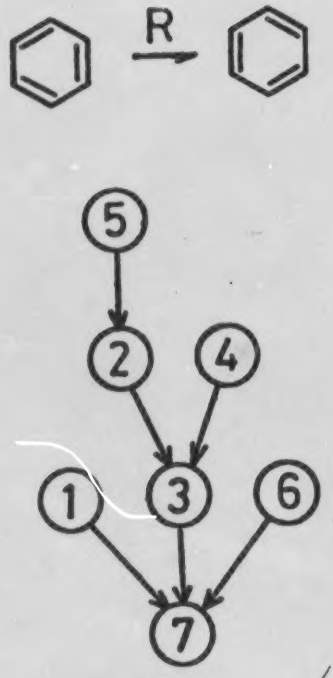


Fig. 7

Position Paper

The question of intensity level in the presentation of material: qualitative vs quantitative; need for math??

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The only certain answer to this question, I believe, is to emphasize that a good teacher must start with a class at its level of preparation and at its level of predeliction (or tolerance?) toward using numbers in any way beyond numbering the pages of the text. I also believe that professors' own preferences and convictions vary so that avoiding mathematics may be an agreeable relief or an anathema. I am convinced that a good enthusiastic, imaginative teacher who starts sympathetically with a class at a low level of mathematical concepts (e.g., the simple proportion of making purchases at a grocery store) can overcome the students' emotional block of anything quantitative. "Oh, that's what it means; that's simple" is a reward worth working to hear.

I think it is important for the non-science student to recognize and properly appreciate that science has a fundamentally quantitative dimension to its operation. This quantifying is essential, from its definitions to the intellectual process by which theories are conceived and then tested. It is a mistake to allow students to miss this very basic mode of scientific thinking. (...Just as it is a shameful intellectual cop-out to allow an old-fashioned descriptive collect-leaves-botany course to fulfill a "science" requirement for graduation.)

The important feature is to involve the students in thinking quantitatively about concepts without getting bogged down in arithmetic, even though calculations can do the manipulative work. For example, the atomic mass concept is a chemical keystone. "Find the formula of a sulfur oxide knowing that a sulfur atom is twice as heavy as an oxygen atom and that the compound is 50% sulfur." This is a good problem because the numbers are simple, and the emphasis can be on the idea. In the same way, if the course uses an historical approach to the development of theories, the clincher in building the atomic theory is always the interpretation of law of multiple proportions data. Here using 80% and 89% as the amounts of copper in the two oxides and 4 to 1 as the atomic mass ratio keeps the student struggling with the main idea not the arithmetic.

My conviction is that carefully chosen analogies can help students accept the obligation of some quantitative thinking. For example, Avogadro's hypothesis is a key concept in any interpretation of chemical phenomena involving gases. (Bring on barometric pressure, air pollution, scuba diving, or what have you!) The analogy of filling a 40-seat bus with football players (a 4-ton load) and then with school kids (a 1-ton load) allows easy calculation of one "molecular mass" given the other one. After the idea is clear, then students should almost be willing to accept manipulating laboratory data involving weighing a bottle filled with oxygen and then an unknown gas.

My impression is that stoichiometry is consistently a turn-off for non-science students. So, accept this fact and emphasize something else. However, the essential idea of stoichiometric ratios can make sense to students. One way is to work out a few "Gee Whiz" problems. For example: the amount of H_2SO_4 that could be made from the sulfur in the soft coal an Ohio city burns that (formerly?) was in the rain falling on western New York state; or the number of ^{40}K or ^{3}H disintegrations occurring in a day in a human body.

Even the most bland "Isn't-chemistry-wonderful" or "Ecology-Today" type of course should have some quantitative foundation for the ideas it presents. The nitrogen oxide environmental problem should be discussed with the aid of Le Chatalier's Principle (predicting the effect of high and low temperatures on an endothermic reaction) but without the Clausius-Clapeyron equation. The whole involvement of the Second Law in interpreting environmental energy considerations from thermal pollution to conservation needs some numerical data to make it intelligible. So many misconceptions about solar energy usage have to be cleared up by using numbers in the expression for thermal efficiency $E = (T_{Hi}-T_{Lo})/T_{Hi}$. OTEC appears to be a miraculous future salvation without some numbers! So too, some real numbers are needed to interpret correctly the statement that nuclear power plants are more thermal polluting than the latest models of coal-burning plants.

Overall, my contention is that the total adherence to qualitative descriptive presentation does a disservice both to students and the science we are trying to get them to appreciate. However, a realistic choice of essential concepts, simple numbers for manipulation, and examples that have impact or significance beyond mere problem-solving is the only way to keep students from retreating back into earlier established phobias about ideas mathematical.

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POSITION PAPER

What balance is proper amongst qualitative understanding and precise mathematical development of topics in chemistry courses for the non-major?

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Ten years of informal observations and data collecting lead me to some conclusions that may have meaning for us here. Students from the Interdisciplinary Approaches to Chemistry (IAC) course, which is directed more to qualitative understanding than mathematical development in comparison with other high school chemistry courses, do as well in college and university chemistry courses (all other things being equal) as those who have been in a more rigorous mathematical type program. However, they seem to have a broader interest in an understanding of chemistry. Perhaps this is because they have been introduced to biochemistry, organic chemistry, environmental chemistry and nuclear chemistry, in place of the usual depth of mathematical presentations. This experience leads me to believe that a course could be similarly constructed for the non-major student at the colleges and universities. There need be no compromise in the quality of the chemistry taught. The concepts, the facts, the theories, and processes (manipulative and thinking) can all be presented.

We don't achieve our goals when we insist on a mathematical level that drives the students out. Our goal should be to attract the students, to help them understand chemistry, its processes and its rôle in our world, and to have them leave our courses not only able to utilize this knowledge in their everyday life, but taking with them an interest in and a friendly attitude toward our discipline.

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POSITION PAPER

What secondary school prerequisites should the students bring to the course (math, chemistry, physics)?

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Every student at the pre-college level has the right to and the need for a functional basic education in science and mathematics. Students are not currently receiving this in the majority of schools in the United States; in Japan, the situation seems to be somewhat better (see attached article, "Science Education--the Japanese Advantage").

I am now convinced that the only way that we are going to see the sciences (including mathematics) take their rightful place in the school curriculum is by moving science from the status of an elective subject to that of a basic requirement--a part of the core that all students study from Kindergarden through Grade 12. This has strong implications for: A) grass-roots actions at the local level to convince parents, school boards, school administrators, etc. that such a change is necessary; B) budgeting at the local school level to accommodate laboratory and field-based science; C) changes in teacher training to enable us to produce more science teachers who are more talented and competent, and D) curriculum reorganization and/or revisions.

I believe now that concurrent teaching of chemistry, physics, biology and mathematics (including an introduction to calculus) should be our principal science program in the latter years of the senior high school. An alternate integrated science might also be taught along side the chemistry-physics-biology program. A semi-integrated middle or junior high school program and a fully integrated science program through the elementary school grades is also in order. For more detail, I am attaching an article from a recent issue of Today's Education in which some of these ideas are outlined.

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Position Paper

Secondary school prerequisites including mathematics

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It would be possible to teach an interesting course in chemistry even in the primary school, that is, with absolutely no prerequisites in chemistry or physics, and with no more mathematical background than simple arithmetic. Such a course would be almost totally descriptive and would concentrate on material familiar to the students in their day-to-day experiences. There could even be a laboratory program, chiefly concerned with the recipes for useful products made by chemical operations on natural materials. This course would be in close accord with Whitehead's ("The Aims of Education") thoughts on the rhythm of science education, where one first deals with the romance of the subject, only later with the precision of scientific inquiry, and much later with the theoretical generalizations.

Therefore, when we consider "minimum" prerequisites for college courses in chemistry for non-majors we really have many options, ranging from the descriptive treatment suggested above to a course that makes considerable use of applied mathematics and measurement.

My position is that two levels of presentation should be available, though not a the extremes. I would rather have students see the descriptive side of chemistry, with its use of models of nature, than to miss the subject altogether. On the other hand, I think it is an unconscionable act for a student to shortchange himself by not studying the subject as fully as his abilities and background permits. Again quoting Whitehead, "The students should feel that they are studying something and are not merely executing intellectual minuets." The totally-descriptive approach simply is not mind-stretching, and we should encourage the teaching of courses that require problem-solving. I refer not merely to numerical problems, but to problems that deal with the fundamental questions of how a chemist comes to feel confident about the structure and behavior of matter. I think the behavior of gases and the kinetic molecular theory probably offer the best situation, because the emphasis is at the molecular level, and that is the essence of chemistry compared to the other sciences.

AAHE Bulletin, September 1981

cience education—the Japanese advantage

article is excerpted with permission The Stanford Observer, April 1981.

an has created an extremely strong cational system to support its tech- gical challenge to the U.S., a Stanford ersity educator reports.

Michael Kirst of the School of Education, ident of the California State Board ci cation, recently investigated Japanese cation at the request of the Japanese stry of Education.

While the U.S. already is experiencing tages of engineers and technological ers, Japan is "much better equipped oduce workers for the economy of the e, which requires high levels of math, ce, and technical skills."

n schools, Kirst notes, the most rtant single school policy determinant udent achievement is time spent on fic instructional tasks. Japanese en attend school 225 days, compared 0 for Californians and "work much r on academic tasks than their ican counterparts."

curriculum differences

n graduates 92 percent of all its en through grade 12, compared to rcent for the U.S. But the contrast demic requirements is even more ssive: Japanese high school grad- must complete at least two years th, two years of science, and three of studies; in California, school district ements vary, but typically demand ne year of math, one of science, vo of social studies.

chemistry, and biology materials adopted in Japan," he relates.

While the U.S. experiences shortages of science and math teachers, Japan makes "an enormous investment" in keeping science teachers up-to-date.

Japan graduates more engineers from four-year colleges than the U.S., despite the fact that their total population is about half that of America.

The overall achievement scores of Japanese in math and science are the highest in the noncommunist world, particularly with respect to problem-solving skills," Kirst says.

"*Ironically, the National Science Foundation developed the new physics, chemistry, and biology materials adopted in Japan.*"

Besides developing an intensive science and math track for their most able students, the Japanese are providing scientific literacy to a much larger proportion of their total school population than the U.S.

"America is producing adequate numbers of Ph.D. researchers for competition with Japan, but Japan's production of technicians outstrips us by a considerable margin," Kirst states.

"Japan requires all high school students to take an extensive language and social studies curriculum, including ethics,

"Japanese high school students rarely question their teachers' viewpoints and are judged by their memorization of facts or concepts on standard tests. They do not use the school library to weave together several information sources and formulate their own interpretation.

"Japanese children are exhorted to 'see the form, but then see through the form and improve it.' While the Japanese are not known for original work that produces Nobel prize winners, they have a good business record with innovative marketing strategies, improvement of imported technologies, and rapid deployment of new technology.

"The U.S. must rethink many of its national economic policies to increase productivity. But a technically skilled workforce is crucial to carry out these reindustrialization policies.

"While California is the leading technology state, it is very vulnerable to Japanese competition. Our college-bound students take about 40 percent fewer math and science courses than even the U.S. national average.

"Our scientific high school standards do not even approach those of the Japanese. Indeed, a major concern of the Japanese Ministry of Education is that academic competition and homework are so intense that Japanese children are neglecting other aspects of child development.

"Japanese high school students repo little enjoyment and look forward to a more relaxed collegiate experience. While the U.S. should not emulate the Japanese system, we must modify ours to meet

College-bound Japanese students take math every year in high school and attain a level of sophistication beyond trigonometry. Only five percent of California high school students study trig. In preparation for college, Japanese students typically take physics, chemistry, biology, and earth sciences. The University of California requires only one year of high school science and two of math, "not even close to highly ranked Japanese university entrance standards," Kirst observes.

Almost half of Japan's high school students attended after-school cram courses for college entrance exams. Overall, about 39 percent of Japan's high school graduates continue immediately after high school with postsecondary education, almost matching the U.S. average of 44 percent.

Japan's math and science curricula stress widespread use of sophisticated instructional materials developed in the U.S. "Ironically, the National Science Foundation developed the new physics, civics, history, political science, and economics.

"While Japan was increasing its social studies enrollments in the 1970s, the proportion of California students taking such courses in grades seven through 12 fell from 71 percent to 45 percent—a drop of 575,000 students."

Fewer electives and more homework

"Japanese high schools offer only a fraction of the U.S. nonacademic electives. Japanese high school students report spending more than twice as much time on homework as do Californians, on the average.

"Japanese classroom teaching techniques revealed some weaknesses the U.S. can exploit in the impending economic competition. A persistent theme in Japan is the use of imitation and rote, methods that are considered outdated by many American educators. the competition in worldwide markets."

U.S. attitude toward science

Between 1968 and 1974, the U.S. national assessment program reported a considerable drop in science achievement scores that has not been reversed in the latest tests, conducted in 1977. Where the first assessment came soon after Sputnik, the second round followed reports of air and water pollution, excessive exploitation of natural resources, and the harmful effects of modern technology.

Ralph Tyler, former head of the Center for Advanced Study in the Behavioral Sciences at Stanford, has suggested there is a correlation between public attitudes toward science and the achievements of 17-year-olds.

"U.S. schools cannot stimulate the necessary student willingness to tackle difficult science and math courses without stimulus from parental and public opinion," says Kirst.

Are U.S. Students Getting Enough Science and Math?

How much *is* enough?

MARJORIE GARDNER

The 1980's are in my judgment the third critical period in the history of U.S. science education. The first critical period came in the late 1800's, when Harvard set precollege study in science as a prerequisite for admission to the College and defined the experiments students should do in high school laboratories. That action had momentous impact: It marked the beginning of science education in this nation as an academic discipline.

The second critical period, inspired by Sputnik, came in the late 1950's, when Americans inferred from the Soviets' success that science education here had become out-of-date. Scientists and educators who looked into the matter said that the U.S. science curriculum lagged in content and method. (On the latter point, students were not getting enough experience in the laboratory or in the field.) That realization led to the reforms of the 1960's that brought new ideas into the curriculum and introduced science teachers and students across the country to new instructional approaches. The results of those reforms are visible today wherever science is taught.

Now, 25 years later, new needs have developed. Failure to deal with them could create very serious problems as the country moves through the 1980's.

Recently, elements of the scientific and education communities, including the National Science Foundation (NSF), committees of the Congress, and the communications media, have recognized that U.S. science education seems to be declining in quality at a time when it is critically important. The public, too, has registered strong concern about the effectiveness of science and mathematics education.(8) School critics cite declining national test scores (2,3,7), the mediocre performance of U.S. students in international assessment studies (1), and the necessity for remediation in higher education.

As a result, agencies and organizations have begun to address the need for some kind of change and improvement in precollege science. (4,5) In 1980, President Carter asked NSF and the Department of Education to study the quality of science and engineering education in the nation's schools. The resulting report, *Science and Engineering Education for the 1980's and Beyond* (6) identifies areas of concern at the precollege level—teaching materials in science and technology, effective use of modern electronic technologies in education, and teacher preparation.

Why is science education a national rather than state or local concern? One reason, of course, is the close relationship of science to the health and strength of the nation. A country cannot have a powerful scientific and technological enterprise without a strong base in science education. That is absolutely fundamental. Economic productivity, world leadership, and the quality of life for all Americans depend directly on the kind and quality of science education the schools offer.

The country needs creative scientists and science teachers. It also needs individuals trained in technical fields. Military recruits must use sophisticated equipment. Managers, including school superintendents, legislators, business and industrial leaders, must possess the science and mathematics background required for rational decision making in a computer-based culture. Also vitally important in a technologically advanced nation is a public that understands science and can use it.

As Americans engage in a national debate on science education, one crucial question will be, How much science and mathematics is enough? One source of relevant information will be the practices of other industrial countries in precollege science education. Consequently, I will describe the

Why is this girl *not* your typical U.S. high school student? Because she's studying chemistry, something only 16 percent of her peers do.

structure and content of precollege science first in the United States and then elsewhere. In presenting these ideas, I will draw on my own experience as a high school science teacher, a university professor and researcher, and an administrator.

Let us begin by examining the U.S. science curriculum at each level. In elementary schools, the intent is to offer some science; however, it's mostly social science. And despite the curriculum projects of the 1960's, many school districts have never adjusted their elementary school budgets to permit the purchase of equipment and materials necessary to teach science properly at that level.

At the middle or junior high level, the commitment to provide laboratory experience seems to be fading again. A number of reasons have been suggested: budgetary problems; inadequate teacher preparation; the ready availability of "read about/talk about" instructional materials; the arrival of a new generation of teachers not so oriented toward inquiry, the laboratory, or the field as those who went through the NSF Institutes of the 1960's and early 1970's.

In the senior high schools, the science pattern generally is the familiar one of biology in the tenth grade, chemistry in the eleventh grade, and physics in the twelfth grade. Only 9 percent of U.S. high school graduates have taken physics, however; only 16 percent, chemistry; and only about 45 percent, biology. Advanced placement courses are available in some high schools, but only for a limited number of students.

The situation is quite different in other countries.

The Soviet Union. In the USSR, students receive 10 years of elementary and secondary schooling. (9) Ninety-eight percent of Soviet students complete the 10 years, whereas only about 80 percent complete high school in the United States. Almost all students in the USSR take science and mathematics throughout the 10-year period. The science program includes four years in chemistry, five in physics, and five in biology. Mathematics is a 10-year program that takes students through calculus. Even in Soviet vocational schools, the curriculum includes more science than in U.S. vocational or comprehensive schools.

Japan. About 90 percent of students complete a primary and secondary school education. Science and mathematics are common throughout the curriculum for all students. In addition, every prefecture has its own science teaching resource center to provide inservice education for its teachers, audiovisual instructional aids for the schools, and other support materials and services.

Since the Japanese believe that all managers in their society need a science and engineering background, Japan deliberately trains more scientists and engineers than the technical work force can use.

Other industrialized countries. The United Kingdom, Western and Eastern Europe, Australia, and New Zealand have similar patterns of extensive instruction in all sciences and in mathematics for most secondary students. The school systems in these countries are able simultaneously to provide both depth and breadth in mathematics and science because students take several subjects concurrently for two or more years.

U.S. schools are almost alone in allowing students to elect science (if they take it at all) in the single-discipline sequence of tenth grade biology, eleventh grade chemistry, twelfth grade physics. For many students, mathematics disappears completely from their schedules after ninth or tenth grade.

With the U.S. approach, students entering higher education will have been removed from the study of biology for two years and from chemistry for at least one year. If they have elected no science or mathematics courses since junior high school, the gap could be as much as five years. Thus the great majority of U.S. students have little or no grounding in the facts, theories, or practice of science for use in undergraduate courses or in their everyday role as citizens.

I've been willing to defend our system of mathematics and science education in the past, but now I'm beginning seriously to question it. I perceive a relationship between the decline in our economic productivity and the quality and depth of our science education. I have become increasingly aware of the difficulty Americans are experiencing in using the science- and technology-based products available to them. I'm beginning to ask if our system is right. I'm no longer sure that it is. It's time to examine it and consider change.

To the question, How much science and mathematics is enough? I think the answer has to be, Much more than we currently teach. In fact, I'm ready to suggest a different system, like the one outlined in the chart below, entitled "A New Model for K-12 Science and Mathematics Education." Here is the schedule I would propose for testing and installing such a model.

Proposed Time Schedule

1981-82: Planning and designing syllabuses (using existing instructional materials)

1982-85: Pilot-testing in selected schools

1983-86: Evaluating, revising, disseminating results, and developing new instructional materials as necessary

1984-87: Testing in full school systems

1985-88: Monitoring, evaluating, adjusting, disseminating results

After 1988: General use as warranted.

Very briefly, let me highlight some of the features I believe a new science curriculum might have. Children in the elementary grades need hands-on science that satisfies their natural curiosity about the world around them and initiates the development of important concepts.

In the middle and junior high schools, where the educational goal is general literacy, not specialization, a largely integrated (or interdisciplinary) approach is still appropriate for all students. At this level, the schools might offer a year each of life science, earth or environmental science, and physical science, with some laboratory and field experience scheduled each year.

In the senior high, where students are beginning to develop different interests and career goals, schools might offer two types of science. I have called them Option A and Option B. Student choice would depend on interest and learning style, not on talent, ability, or even on career goals.

Option A would include the traditional secondary school subjects—chemistry, physics, biology, and mathematics—as separate subjects. Students would study all of them concurrently, however, in the final three years of secondary school. This separate but concur-

A New Model for K-12 Science and Mathematics

Grade Level	Science	Hours a Week	Mathematics	Hours a Week
K–6	Exploring the Natural World	2	Arithmetic	5
7–9	Semi-Integrated Science Life Science Earth Science Physical Science	5	Algebra/Geometry	5
10–12	*Option A.* Concurrent Specialized Sciences Biology Chemistry Physics	5 (or 7, with 2 double = period labs)	Advanced Algebra Trigonometry Calculus	5
	Option B. Integrated Science	5–7 as above	As above for academic students; more immediately relevant mathematics for vocational students.	5

rent option would more closely approximate the pattern that exists in most other industrialized countries.

Because of the varying amounts of time assigned to each subject in any one year, this option would not take any more time in the school curriculum than is presently assigned to science and mathematics. Here is how Option A might be scheduled for grades 10-12:

Grade	*Science*	*Periods a week*
10	biology	3
	chemistry	1
	physics	1
11	biology	1
	chemistry	3
	physics	1
12	biology	1
	chemistry	1
	physics	3

This concurrent pattern would permit schools to stay fairly close to the plan now common in the United States. There would be no change from a total of five periods a week for science. Moreover, biology would dominate in tenth grade; chemistry, in eleventh; and physics, in twelfth. The advantage of the proposed system lies in the fact that students receive continuous exposure to all three science areas throughout the three-year senior high school period.

Mathematics would occupy a daily place in this precollege curriculum, but the present syllabus could be accelerated to include an introduction to calculus in high school.

Option B would consist of a rigorous, integrated science curriculum throughout the three years of senior high. Accompanying it would be a companion integrated mathematics program, also rigorous and closely related in context to the appropriate science.

Either Option A or Option B should be mandatory for high school graduation.

With either option, students who complete high school would have the strong, up-to-date background in science and mathematics necessary for broad career options and the flexibility to change careers as their interests and the nation's needs change.

Women and minorities, two groups who have been underrepresented in science and technology but who are important members of the nation's talent pool, would automatically obtain the solid, technical precollege background that opens access to a wide spectrum of educational and career opportunities.

This proposed modification in the school curriculum would also reduce or possibly eliminate the need for remediation, a serious problem in both the precollege and the college years. Remediation requires large amounts of time, effort, money, and emotion. The psychological damage to those who have to take remedial courses can be severe.

The changes I suggest might also help to demystify science for general students, making them more comfortable as they use science in their everyday lives.

Is a more intensive science and mathematics curriculum realistic? I think so. This nation is sufficiently educated and affluent to set high quality science education as a goal and to implement it. Anything less is a cop-out of potentially serious proportions.

Science educators cannot, however, suddenly bring about such changes. Close communication with key groups of decision makers, both in education and among the public, is essential. If we believe that it is important to increase the amount and standard of science and mathematics taught in the schools, it is our responsibility to help school board members, parents, administrators, and others understand the goals, costs, and benefits.

Some science educators will say that there isn't the money, there isn't the time, there isn't the community support to take new steps in science education at present. I disagree. We must begin long-range planning and experimental change now as an investment in a stronger and healthier America. The leadership position of the United States, its economic productivity, the quality of life, personal satisfaction—all these are heavily dependent on our taking the initiative in improving science education.

This article is excerpted from an address Dr. Gardner presented at the 1981 national convention of the National Science Teachers Association in New York City. The views expressed are hers and not necessarily those of the National Science Foundation.

Dr. Gardner was until recently director, Science Education Resources Improvement, the National Science Foundation. She has returned to her position as professor, Department of Chemistry, the University of Maryland, College Park.

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Position Paper

Instructional Methods Related to Class or Institution Size.

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(see also position papers by: Kirschner, Oki, Ramette, and Hosoya)

Both Japan and the United States share the problem of developing the best possible instructional techniques for large lecture and laboratory classes. Whatever the type or size of the institution, the students must be well-trained and emerge from their institution with a comparable education. Although Japan does not have as large a fraction of its student population in their tertiary education system that we call either the junior college or the liberal arts college, there are in Japan many institutions smaller in student body size than the Imperial universities and large private universities. The major issue is to point to differences in instructional techniques inherent for the student whose primary educational goal is not the sciences.

Experience in the writer's institution with a total enrollment in excess of 55,000 suggests the following.

1. The need is great for the course or courses part of the theme of this Seminar. Enrollment in the writer's institution in this course has in some years approached 1,000 students out of a total enrollment in the first-year chemistry classes of some 6,000.

2. The need for exceptional teacher skills are more in evidence for this group than for any other course stream, normally a part of the general or introductory chemistry program.

3. The need for laboratory is as, or more, important for these students than for those in a major or science program. These students may never experience the hands-on phase of instruction in any other subject taken in their college curricula. Even those experiments considered as bordering on the trivial can be made challenging. Many can be planned for shorter periods of time, requiring fewer hours of instructional time than those designed for students taking more chemistry and more science.

4. Special instructional and tutorial tools play an important part at this level, regardless of the size of the class. The frequency of encountering under prepared and under motivated students in such a course is greater than for others, for instance, engineers, pre-profressionals, and majors. Thus, one-to-one tutorials, computer assisted learning systems are in use or are being developed for our particular situation. Video and audio tapes covering many aspects of the course, essentially based upon demonstrations that have been seen live are available and given frequent use.

5. Another important segment of student population likely to be found in this course will be the minority, inner city, and foreign students. Though not exclusively, many of these will be in need of special learning techniques, some of which have been noted in 4, just above. Available to all are tutorials held hourly five days of the week. This tutorial program necessarily is limited by the number of teaching assistants. Those institutions where all instruction is by senior staff are faced with a greater teaching time commitment. Whether the number of students needing special help in the liberal arts college is greater than the large university is a matter for discussion and suggestions for solution under other items of the agenda.

6. In a country such as the United States, and perhaps not exclusively since Japan may be faced with similar problems, new fiscal attitudes are being taken by the administration and the government bodies. Every effort must be made to guard the laboratory, especially for this group of students. From experience, it is evident that with retrenchment, expensive instruction is given a very close look. The importance of the laboratory in an overall curricula can be proven by one of the writer's experiences. The enrollment in this "non-major" course fell from nearly 1,000 to about one-third of this number when the course was converted to a lecture only format. Students and curricula committees alike recognized the importance of the laboratory.

7. The Teaching Assistant, where such is used in the laboratory and recitation work, must be carefully chosen for communication skills, patience, and obviously, competence in subject matter. Special training methods must be devised at the beginning of every school year for such Teaching Assistants to assure maximum use of their inherent skills.

8. The writer may not be speaking from a sufficiently broad experience base; however, he feels there are not large differences in instruction that arise simply from the size of the institution or the size of the class. The importance of presenting a stimulating and current course is the same in any institution or any class.

The Question of Class Size

Stanley Kirschner
Wayne State University

Class size is a serious question associated with the development of an ffective chemistry course for non-majors. The tendency in the United States as been to go to larger and larger classes in an effort to conserve funds, aculty lecture time, etc. It is possible to create a course of this kind hich can be taught effectively to large lecture classes (as well as to small nes) provided care and attention are given to several matters. These matters ncrease in importance as class size increases.

A. Lecture Room and Class Size.

As class size increases, it is important that appropriate room space be available. Of course, the lecture room must be large enough to accommodate all students and must be arranged in such a way that students have a good view of the lecturer, the lecture desk, and any audio-visual material and projection screens which will be used during the course. Further, it must be appropriately designed so that examinations can be given conveniently, and, it must have appropriate demonstration facilities available for use by the lecturer including facilities to utilize television and overhead projector equipment.

B. Class Organization.

If the lecture method is going to continue to be used for such a course, it is essential that a large lecture class be broken down into small groups (ca. 25-30) for laboratory and recitation class instruction. These are necessary in order to provide the personal attention required in laboratory and for explanations of the difficult points on which students will have questions. Whenever possible, the same teaching assistant should handle the same group of students in both recitation and laboratory sections. Recitation sections should be used primarily to answer questions regarding lecture and homework material, and they should also provide an opportunity for short quizzes on especially difficult material.

C. Help Sessions.

Several one-hour Help Sessions should be available to students who desire additional assistance with this course. They should be optional as far as student attendance is concerned, and they should meet regularly.

D. Office Hours.

Both the lecturer and the teaching assistants should maintain a posted set of office hours, during which students in their sections may come to see them with questions about the course.

E. Course Evaluation.

A course evaluation form should be made available to students periodically, so that the course staff can be informed about problems regarding course organization, lectures, textbook, laboratory, and personnel.

Topic 17 (continued)

F. The "Dial-Access" System.

If possible, the course lectures should be tape recorded and a system should be developed (herein called the "Dial Access" system) by which students will be able to hear previous lectures in the course, in case they wish to re-hear a particularly difficult lecture. It must be emphasized that students should use this system only for this purpose, and not in lieu of attending the original lectures themselves. It should also be pointed out that the blackboard and audio-visual material will not be available on this Dial-Access System.

G. Technology and Hardware.

1. Television.

Videotape equipment should be available for this course for the televising and showing of "pre-lab" instructions and demonstrations. This not only has the advantage of saving the time of the students and teachers, but also permits students to re-play those parts of the instructions which they did not understand (e.g., instructions on how to read a Vernier scale or how to weigh on a single-pan balance). Further, such equipment is very useful for showing lecture demonstrations of dangerous operations (e.g., the Thermite reaction).

2. Microcomputers.

It seems clear that the introduction of microcomputers will continue to gain acceptance in General Chemistry courses and that appropriate experiments will continue to be developed which will be designed to acquaint even the non-majors with the use and value of microcomputers in science.

3. Tape Recorders.

Help Session rooms can be designed so that they are equipped with tape recorders and earphones - thus allowing students to play pre-recorded tapes designed to explain especially difficult topics in chemistry (e.g., the Shakhashiri, Schreiner, Meyer Audio-Tape Lessons).

4. Laboratory Instrumentation.

Simple spectrophotometers (e.g., Spectronic-20) and pH meters should be a part of the laboratory in a non-majors course so that students can gain some insight into the types of things which scientists do and some of the instrumentation they use to do those things.

H. Teaching Assistants.

It is proposed above that teaching assistants will comprise an important part of the instructional team for the non-majors course. It must also be stated, however, that the teaching assistants in such a course must be especially able persons who have a strong interest in teaching. Graduate students in chemistry who are also teaching assistants can easily miscalculate the level of ability, interest, and background of the students in a non-majors course, and care must be taken to avoid problems which would develop if the wrong type of teaching assistant is placed in such a course. It must be emphasized that the teaching of large classes is a team effort, and that all members of the team must work closely together and cooperate fully if the course is to be successful.

It cannot be over-emphasized that non-scientists directly control science in every country of the world, and the rate at which science will progress is directly dependent on the degree to which there exists a large, informed body of non-scientists in the population.

Stanley Kirschner
Wayne State University

Position Paper

Are current printed materials adequate?

Instruction in chemistry for the non-major student.

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There is no rational answer to this question, of course. My own bias and experiences convince me that really good teachers can and do find the current materials adequate, even as they search for and demand more new and exciting examples and illustrations to heighten student interest in learning.

As a whole, chemistry teachers seem to agree on the principles that should be taught in beginning courses, and most teachers appear to have confidence in their ability to get students to learn these principles using existing materials. However, even though it can be argued convincingly that all beginning chemistry students could benefit immensely from a well taught, reasonably demanding, traditionally oriented, principles-based course, the truth is that such a course is unacceptable to so many students and teachers that major efforts are underway to develop materials that will teach the principles in an everyday life context. We are still in the early stages of this development, and, while a great volume of material - some of it quite good - has been produced, most teachers view the entire movement as still in an experimental stage. In this sense, the printed materials in this category might be considered less than adequate. What might help us get a better reading on their adequacy is to have a clear view on what materials are available and why they were prepared.

Although there are a great many reasons that so many teachers in the United States have turned their attention toward teaching chemistry as part of everyday life, the following facts present the situation as compellingly as any.

1. Only 16% of all the high school students enroll in chemistry classes. High school chemistry teachers attribute this low enrollment to student perceptions that chemistry has no direct bearing on their lives.

2. An analysis of the findings of the recent national assessment of educational progress indicates that students know little about the nature and causes of important science related societal problems. For example, 88% of the 17 year olds do not know that plastics are petroleum products; 63% do not realize that cars are the major urban polluter; less than one third know that sulfur emission from smoke stacks results in acid rain, and 54% do not realize that most electricity is generated from coal, gas and oil.

3. A recent Cornell University study showed that over half of the colleges and universities in the United States are committed to teaching and/or to research involving studies of the science/technology/society interaction. This commitment recognizes the need to do something about the widespread and expanding public skepticism toward science and technology.

4. Numerous other countries including Japan, Thailand, England, Scotland, Israel and Canada have felt the need to provide chemistry instructional material that focuses on chemistry/industry/society interactions.

All of this indicates that the necessity of improving public understanding of science is an imperative of our time. As chemistry teachers we have the unique responsibility of helping the public to understand and appreciate chemistry. As we prepare, react to and select materials for our teaching, this responsibility should be very much before us. It might well temper our judgment concerning the adequacy of materials, particularly those to be used in the non-major course.

All of us are familiar with some if not much of the material having an everyday life focus that has been prepared for non-major courses. Each of us has some idea of how well this material will work with our students and how closely it comes to meeting our personal and professional needs and goals. Perhaps what is most needed now is a greater sharing of our impressions of these materials among ourselves and a series of activities that will help us crystallize our thinking on the kinds of things that will work and the kinds of things that will be acceptable to us as good science, good chemistry, and good ways of teaching ordinary citizens to appreciate chemistry.

For those who might be interested, here are a few of the major projects and sources of material that emphasize chemistry in everyday life:

1. Courses and Projects.

   a. The Individualize Science System published by Ginn and Company is a set of modules for non-science students that includes a number of chemistry topics. Two of these are kitchen chemistry and fossil fuels.

   b. Interdisciplinary Approaches to Chemistry. This is a series of seven modules developed by Marjorie Gardner and her associates at the University of Maryland. It is based on the idea that chemistry is to be enjoyed, cultivated and comprehended; that it is part of our culture in our everyday lives.

   c. ALCHEM Chemistry Materials Project. This is a series of fourteen books which constitute a high school chemistry elective, primarily for students interested in chemistry and the environment. It was developed by Frank Jenkins and colleagues in Alberta, Canada.

d. Interactive Teaching Packages. These packages focus on chemistry/industry/society interactions and are pupil-centered rather than teacher-centered. They were developed by Professor Johnstone and Reid of Glascow University.

e. The CHEMCOM Project. The American Chemical Society has recently received a grant from the National Science Foundation to develop a series of modules that will be the first part of a high school chemistry course for non-science students. The project is known as the CHEMCOM (chemistry in the community) Project.

2. Sources and Individual Items that might be used in Lectures or Laboratories.

a. A list of such sources is given in the chapter entitled Practical Applications of Chemistry by E. K. Melon and John McDevitt in "Sourcebook for Chemistry Teachers" that was published as part of the 6th International Conference on Chemical Education. Copies of the Sourcebook are here for your use.

b. Environmental Chemistry is another chapter in the Sourcebook. This one is by J. Arthur Campbell and it includes a list of questions and answers on various aspects on environmental chemistry and chemicals in the environment. These questions and answers were taken from a series entitled eco-chem that appeared in the Journal of Chemical Education from 1972-1977.

c. The Journal of Chemical Education has at least three other features that include items of this kind. In the late 1960's and early 1970's Bob Plumb edited the column entitled Chemical Principles Exemplified and Bob Brasted edited one called Chemical Vignettes. Between 1977 to 1980 the secondary school section of the Journal carried a feature entitled Chem. One Supplement. Since 1980 the Journal has run a column by Ron De Lorzeno entitled Applications and Analogies.

Position Paper

Are current printed materials (texts, manuals, laboratory workbooks) adequate?

William F. Kieffer, College of Wooster

The adjective "adequate" makes this question difficult to answer. Certainly, a wide variety of text materials exists; not much in the way of laboratory manuals specifically designed for the non-science course is available. The texts began to appear about ten years ago. The most successful, John Hill's*, has already had several editions; the weakest probably never sold out their first printings.

The course for the non-science major does not follow any established style or pattern as do most of the courses offered in the science major programs. An interesting (and inevitable) diversity exists, the consequence of a variety of professorial convictions and enthusiasms. For those who favor an historical approach, a philosophical approach, a sophisticated cultural approach, an environmental approach, even a "whee, isn't chemistry fun" approach, some kind of a text exists. The implication of this situation is that no book can be all things to all users. A text author should choose an audience and build a book with that group consistently in mind, otherwise a weak miss-mash results. I see no way for a book to be popular or even "adequate" for all potential users.

Another circumstance must be recognized when analyzing the adequacy of existing text materials. There are many institutions where a really outstanding teacher has accepted the challenge of being a missionary to the non-professional ignored. For this really imaginative, enthusiastic professor, no text is "adequate", regardless of how closely it parallels his or her approach to the subject. The really successful course for non-science students is the one taught by the innovative professor who does things in his or her own way and whose enthusiasm carries the students along to levels of interest and accomplishment that no textbook can generate.

Asking those of us who have authored texts for this course a question like this has to produce an evasive answer! I have been guilty of contributing to the proliferation twice! Yet I know undeniably that the best versions of the course I have taught were in recent years when I used neither of my own books. Using one's own authored text is a deadly experience.

A comment on a peripheral issue may be appropriate. There exists a wide range of excellent suitable supplementary material for this type of course. When concerns began to focus on environmental problems a few years ago, many well chosen anthologies of reprinted articles were published. Most of these are outdated now but several, notably the reprint collections from Science, published by AAAS, are very useful.

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Position Paper

How essential is the laboratory?

Anna J. Harrison, Mount Holyoke College
(see also position papers by: Saito, Hill, Shakhashiri)

There are, to me, at least three types of non-major courses:

1. An introductory course for students who do not need to develop technical competence in chemistry to achieve their professional goals,

2. An introductory course for students who need to develop limited technical competence in limited aspects of chemistry - i.e. agriculture students, and

3. An upper level course for students who have made a professional commitment to professions such as journalism, law and business.

Whether a laboratory can or cannot be made an integral part of the course determines to a large degree the design of the course. Demonstrations which involve the students in the planning of the demonstrations can simulate in part the experience inherent in individual laboratory experiments and could surpass in value the laboratory exercises characteristic of many laboratory assignments. Demonstrations which require the participation of the student in the planning of the demonstration requires that much of the class time be dedicated to the demonstration.

A rewarding laboratory experience is exceptionally valuable to a student in an introductory course. At first hand, the student experiences to a limited degree the processes of science. This is an essential experience to any student who will later endeavor to understand the powers and limitations of science and technology and particularly valuable to the student who will not later develop technical competence in the laboratory. The student also acquires a limited number of techniques. These techniques may be essential for the student who needs to develop limited technical competences - i.e. the Ag student.

Laboratory work in the usual sense may be of less value in the upper class courses. Here the corresponding time could be better spent visiting laboratories and other technical institutions.

a) In general, I am not in favor of exercises, except as a means of acquiring techniques, and I see no reason why environmentally oriented experiments are more to be favored than many other types of experiments.

b) My choice would be one three-hour laboratory per week. I would prefer one three-hour laboratory every other week to one two-hour laboratory every week. A recitation period preceding the laboratory is not necessary - or even desirable.

c) The nature of the laboratory work must be appropriate to the capabilities and commitment of the staff.

d) My experience is that the value of the laboratory work is directly related to the care with which it is reported. Data, calculations and brief answers to questions do not constitute an adequate report. I am willing to base a grade on whether the student endeavors to use the laboratory period constructively and endeavors to report the work adequately. It may be feasible for the laboratory instructor to spot check the laboratory reports during the laboratory session. Place emphasis on what is good about the report.

e) My experience leads me to believe that, for an introductory course, an experiment to be carried out quantitatively should first be carried out qualitatively and that the qualitative experience should be essential to the planning of the quantitative experiment. There should be some quantitative work. How much should be quantitative depends upon the goals of the course.

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Position Paper

A Laboratory for Nonscience Students

John W. Hill, University of Wisconsin-River Falls (see also position papers by Saito, Harrison, and Shakhashiri).

What about laboratory? Should there be a laboratory for the nonscience students? Laboratories are expensive in a time of tight budgets and demanding of staff time when we teachers already have more than we can do.

All of us have felt those constraints. I believe, now more firmly than ever, that nonscience students should have laboratory experience. I just as firmly believe that the experience should not be the traditional one in which students test laws that are already well-proven, redetermine physical constants which are more easily found in a handbook, and analyze "made-up" unknowns. The main goal should be to get the students involved in investigating the real world. We should use made-up samples only to show what a positive test looks like or to calibrate our apparatus.

The role of chemists in society is changing. Indeed, it must change if chemistry is to survive as a profession. In the past, most chemists have concentrated on making new products--"better things for better living." While we will continue to need new and improved materials, more and more chemists will have to become involved in designing "better processes for a more livable world." Chemists will also become more involved in monitoring air and water quality, chemical dumps, and other aspects of our chemical environment. It is these changing roles that we should emphasize in the laboratory for nonscience students.

I believe that a chemistry lab for nonscience students should, as far as possible, adhere to four guiding principles. First, the experiments should be short--one hour if possible, not more than two hours. That makes labs easier to schedule and it is easier to maintain student interest. Second, the experiments should use cheap, everyday materials. Ask students to bring materials from home or buy them at the store. The need for "cheap" is obvious to most of us. Perhaps more importantly, students are more comfortable using familiar materials and more interested in such experiments. Third, we should avoid as many of the more hazardous chemicals as possible. Total avoidance of hazard is impossible. And even if it weren't, it would be unwise. We should try to teach them how to handle dangerous substances safely, a practice that we hope will carry over into their everyday lives. And fourth, we should strive to devise some interesting experiments, yet ones which still illustrate important principles.

Allow me to describe how we try to meet these four objectives in our laboratory program at the University of Wisconsin-River Falls.

We will start off with a section or measurement. We make metric mayonnaise or SI salad dressing. Students may also prepare "Sterno" or "Canned Heat." Next we do an experiment to illustrate chemical change. We grow crystals of iron(II) sulfate, potassium ferricyanide, potassium ferrocyanide, etc. Then we mix various solutions and look for new colors and shapes of crystals. (One product is Prussian blue.)

In electrochemistry we now use glacial acetic acid in toluene--safer, cheaper, and easier to prepare--in place of hydrogen chloride in benzene.

We have an agricultural chemical experiment on antibiotics in animal feeds. Chlorotetracycline and oxytetracycline give different colors when treated with certain chemical reagents. The test is simple and dramatic. And it illustrates one minor role that chemists play in modern agriculture.

We have several experiments on foods. We have modified the old Baeyer test so that it works as a test for unsaturated fats. (The usual Baeyer test doesn't work; fats are immiscible with water.) We have the test working well on a qualitative basis. We have hopes that it be made quantitative and thus replace the iodine number as a test for unsaturation. Another experiment evaluates a variety of organic acids and salts as mold inhibitors in foods.

One of the most interesting--and original--experiments that we have developed is making a copper mirror. They said it couldn't be done, but we plate copper on glass to make a mirror. With our copper mirror, everyone appears to have an Arizona suntan.

We can make an infinite variety of soaps--hard, soft, transparent, and with varying solubilities. Just neutralize any of several fatty acids--lauric, myristic, palmitic, stearic, or oleic--with sodium or potassium carbonate (or hydroxide) or with triethanolamine. Or we can make soap the way Grandma did, using lard and lye. Like colored soap? Just add a piece of crayon to the fat.

A cosmetic unit has added a great deal of interest to our course. We can make toothpaste, cologne or aftershave, and a lovely vanishing analgesic balm. We can make shampoo, but it isn't worth it. Just buy the cheapest stuff you can find and add your own conditioner--an egg or a tablespoon of gelatin.

Student response to the lab has been quite favorable. "Why can't we do more lab?" is a common question. The answer to their question, all too often is twofold: lack of money and lack of staff time. I believe, however, that the lab should have high priority in any department concerned with the future of the profession.

(These experiments are described in detail in Scott, Hill, et al., Chemical Investigations for Changing Times, 3rd edition, Minneapolis: Burgess Publishing Company, 1980.)

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Laboratory Programs in General Chemistry

Bassam Z. Shakhashiri, Univ. Wisconsin-Madison

Comments, Suggestions, Solutions:

All we know and teach of chemistry is founded on experimental observations. Experiments in general chemistry should introduce the student and stimulate his interest in chemical systems and their properties; the general approch is to enable the student to develop certain minimal skills and techniques that are necessary to the performance of scientific experiments. What a student learns from laboratory experiments depends to a very large extent on how well he interacts with his instructor while performing an experiment. Considerable efforts should be devoted to train lab instructors and to increase their effectiveness.

In recent years the cost of laboratory instruction in general chemistry has become an overriding consideration. Some major institutions have changed their introductory college course structure by eliminating lab work during the first term. Thus, lab experience is denied those students who do not go onto the second semester course (for whatever reason). Although several arguments are presented in favor of this approach, the main consideration seems to be financial: lack of sufficient funds to support graduate teaching assistants and the skyrocketing costs of chemicals, supplies, and expendables.

The three major costs of laboratory programs are staff, equipment, and chemicals. We should discuss how resources can be used to conduct laboratory work in a safe, economical, ecological and educationally-valid approach.

The kinds of experiments to be stressed are:

Stoichiometry
Acid-Base Behavior
Thermochemical Changes and Measurements
Chemistry of the Halogens
Colligative Properties
Qualitative Analysis as an Application of Chemical Equilibrium Principles
Synthesis and Characterization of Coordination Compounds
Electrochemistry
Chemical Kinetics
Organic Functional Groups (unknown identification)
Synthesis and Characterization of Polymers
Half-Life of Th-208
Enzyme Catalysis

Every fall semester about 75 graduate teaching assistants are asked to participate in teaching over 3000 students who enroll in introductory college chemistry courses at Wisconsin. All courses are offered in the format of weekly lectures given by professors along with quiz-discussion and laboratory sessions. Typically, the teaching assistant (TA) is responsible for two sections each with a maximum of 22 students; each section meets twice a week for discussion and once a week for laboratory (2-3 hours).

Laboratory Programs in General Chemistry
Bassam Z. Shakhashiri

Several efforts are directed toward enhancing the role of the TA as a discussion leader and a lab instructor. The goal is to make the participation of graduate students in teaching freshman chemistry both effective and rewarding. The efforts include organizing and/or offering: pre-semester training programs (3 1/2 days), mid-semester performance diagnostic survey, graduate-level seminar course (Chemistry 901: The Teaching of Chemistry), weekly staff meetings, Project TEACH materials, use of videotape equipment for self-assessment, class visitations and others.

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=Abstract= US-Japan Seminar on Chemical Education
The Use of Micro-Computers in
Chemical Education

John T. Shimozawa
Saitama University

The Purpose of this talk is to raise some topical problem in the chemical education at both secondory and tertiary levels, and to point out the way of resolving these problems in using micro-computers.

After considering the use of micro-computers in several ways, the participants could discuss the future of this technique either in the light of their own experiences or their own personal opinions.

The presentation will discuss the followings point.

1. The modern status of education. (a)Influences of the popularization of higher education. (b)Attitudes of the university students against study. (c)Balance between the social demands and support from schools.
2. The roles of Science Education under to-day's circumstance. The roles of Science Education now-a-days are the same as before. i.e., to understand the rules of nature (Physics), substances (Chemistry), Life(Biology), the globe and cosmos (Earth Sciences).
   In addition, I think the main purpose of science education is to give rationalism to daily life. The way to establish a rational approach is to teach the way of setting the system to be considered, and how to balance the different parameters in the system. i.e., the concept of equal can be understood

through scientific phenomena.

Effects of the introduction of micro-computers into science education.

(1) to initiate the students' motivation to learn science

(2) to teach science courses by the "individual learning method"

(3) to assist the lectures as teaching aids

(4) to evaluate the curriculum given to students

Examples the Micro-Computer Uses.

(1) Teaching Aids using in the class

    a. Electron Density of Hydrogen Atom

    b. Molecular Vibrations of H_2O

    c. Rotational Spectrum of Diatomic Molecules

(2) Individual Teaching Program

    a. High School Chemistry

    b. Periodic Table the Elements

    c. Gaseous Molecular Motion

Disadvantages introducing Computers into chemical education.

(1) Lack of flexibility

(2) Lack of involvement in practical chemistry

(3) Others —— to be discussed at the seminar.

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USE OF MICROCOMPUTERS IN CHEMICAL EDUCATION

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1. INTRODUCTION

Computers have been used in research work in Chemistry since 1953 in Japan. The main tasks for the computers are to treat the data in theoretical proofs; to calculate complicated equations; to examine experimental results, and so forth. Progress of the computer provides wide uses in computation not only in scientific work, but also in our daily lives, because the cost for computation has been decreasing year by year.

The great advantage of the computer in addition to those mentioned above is the display on the printer or on the TV screen. These displays have been in use for large computers since 1975, however, it is quite practical to apply this technique generally now since microcomputers were introduced at low cost in 1978.

The TV-Linked computer systems, such as the Captain System developed by Telephone network in Japan, is now available to be set up in private homes. The users make digitalized requests according to their interests, and the display will tell them the results right a way.

These new developments help people to handle computers even if they are not experts in computer programming or software. In other words, this is the time of the easy computer age. So I think that all chemists must emphasize the use of computers as much as possible.

It is true, that in Japan there are some people too conservative to use computers in chemical research, and some also hesitate to use computers in chemical education.

The use of computers in chemical education in Japan is less developed than in the U.S.A., however. I would like to give some examples of using the computer in chemical education in my laboratory. There were two approaches. First: to use the "COMPUTER ASSISTED INSTRUCTION" or "CAI" data to evaluate the highschool chemistry curriculum. The second: to display chemical phenomena which are difficult to show to students.

2. USES OF COMPUTERS IN CHEMICAL EDUCATION

"Computer Assisted Instruction" is called the CAI method. This covers a wide range. Computers are used to analyse the scores of the students, and the evaluations are also characterized through the data. These treatments are called: "CMI(Computer Managed Instruction)".

CAI data are very detailed, but the analysis is difficult, because of the fluidity of the data, therefore the CMI must be developed by the users.

The CMI seems to be used only in the calculation of the score and to make distribution curves using standardized statistical methods. The users are not satisfied, because they use only apparent data, but no consideration behind the score. So there may be many problems to be solved on CMI in the future.

In Japan CAI is still becoming more generally used nowadays, but compared with the situation in the U.S. we are very much behind. This is mainly because of the shortage of financial support from the government, and the attitude of the teachers. For example: if we use CAI for a class of 50 students, we need a terminal for each student, which would cost about half million yen each, and the total would come to at least 25 million yen (15.000 dollars).

The finances for each school for such investments are limited, particularly for hardware. In order to get such support from the government, special proposals will need to be made for many years, and there are not readily accepted by the government. CAI were set up at three schools in Japan; i.e. Koyamadai Highschool, Katsushika Middle school in Tokyo, and Takezono Primary school in Tsukuba. However, there are many places where only one terminal is available, for example at the prefectural educational centers which are training institutes for teachers.

At the universities, there may be several CAI, which are experimental facilities for preparation of software and small scale tests for developments, at this stage. These are called: The Education Technological Center of the University. The reports from the center appear in the Journal of Educational Technology in Japan (a quarterly journal).

The Japan Society for Science Education was established in 1976, it is an outstanding Society for science education, which emphasizes strongly the use of computers for science education. During the annual meeting of the Society almost 50% of the papers are related to Computer Science in Education.

The reports on Educational Technology in Japan can be divided into four categories: 1) Comprehensive Research. 2) Developmental Studies. 3) Transferability Studies. 4) Feasibility Studies. These projects are introduced in the Journal of Science Education in Japan, Volume 3, No.4 in English.

The attitudes of teachers in schools and of professors in centers of higher education tend to be conservative, and they tend to oppose the introduction of educational technology into their classes. A possible reason is that they like to teach the same way as they were taught during their own school years and they believe that the established method of teaching is very good. However, the situation concerning youngsters has changed: the youth are fond of play rather than to seek the truth behind appearances; the objective for schooling is completely different from that of the old days. So the methods of teaching should be reconsidered and innovations introduced. Some teachers are against the introduction of the computer and say that the computer is just a machine, but teaching should depend on human relationships; there must be lively discussions between pupil and teacher. However, the classes are very large, consisting of 45 to 48 pupils. Also there are great differences in the students' abilities to study; the teacher should teach the items depending on the ability of each pupil. In order to do so, CAI is much better as an individual teaching instrument, because the teacher can collect the data from each pupil. CAI is also applicable for home work as a self learning tool.

There is another argument against the introduction of CAI by teachers. If CAI is used for teaching languages, a teacher who is responsible to teach German grammar, for example, may loose his job. For the beginners' classes in German, the teachers just repeat the words "der, des, dem, den" for three or four hours, they prefer to do so, instead of studying the interpretation of the new German Literature. They do not want to change their teaching habits.

IN the case of introducing CAI, it should be kept in mind that there are many people who are not willing to accept new methods of teaching; at the same time it should be recognized that even if we could introduce CAI, we must retain the good principles of the older teaching methods.

In case of Chemical Education, there are other points against the introduction of CAI; Chemistry is a concept using a DEDUCTIVE way of thinking, whereas the approach used in the CAI is INDUCTIVE. Therefore, we have to develop a newer usage of computers in chemical education.

3. EVALUATION OF HIGHSCHOOL CHEMISTRY CURRICULUM AT CAI TECHNIQUE.

3-1 Purpose of the Project.

In 1971 the Ministry of Education requested the establishment of a highschool chemistry curriculum for non-science majors.

There was also another project team for a highschool chemistry curriculum for chemistry majors, which was lead by Professor Oki, of the University of Tokyo.

The highschool curriculum proposed by such a committee should be examined by the highschools before the publication of the final report. The CBA and CHEM Study in the U.S. were treated in that way.

In the case of Professor Oki's report, the textbook wa not examined by the pupils, but by the teachers on the committee. The book was used as a textbook at several highschools after publication, however, the teachers who used that book were not committee members.

The new approach to the teaching of chemistry must be discussed by the committee members, but in order to use this new crriculum, the opinion of the students is very inportand, and that must be reflected in the curriculum. We do not have a system to collect opinions of the pupils before or fater a proposed curriculum is published. In connection with Professor Oki's report in 1975-78, Professor Tanizaki of the Technical College of Nagaoka, set up a special committee for this purpose. Fourteen highschools were selected from all over Japan. The opinions from the students were summarized by the committee and the Oki report was re-written by the committee members. This new book was also published in 1980 by Maruzen Book Co. The title is: "Fundamentals in Chemistry".

We have found through this feedback that the pupils "opinions" do not exactly reflect their real opinions, because the comments were interpreted by the teachers. This means that the evaluation of the Curriculum has already been made by the teachers, who were not on the Oki Committee. Each comment included both teacher and pupil reaction.

Through this experience, we decided that in order to evaluate the curriculum, we have to collect the comments from the pupils derectly, and the CAI instrument can be used for this purpose.

The CAI system located at the Koyamakai Highschool in Tokyo consists of a minicomputer, a control system and 50 terminals, which is shown in Figure 1.

Figure 1. Terminal for pupils

There are switches which indicate whether the pupil uses the machine or not; buttons 1 to 5 for the selection of the answers, and an indication window to which numbers the pupil must go are also shown in Fig. 1.

Individual scores are as follows: time taken to finish the card, numbers selected by pupils corresponding to questions. The teacher can see the print-out for each pupil, and an example is shown in Fig. 2.

Figure 2. Print-out of the individual score.

We used the CAI instrument for the evaluation of the highschool chemistry curriculum. We tried to collect the reaction of the pupil as functions of time, answers and also questionnaires. The indications are used through cartds which are in the same sequences and sentences than the textbook. In order to judge the reaction of the pupils, the questionnaires, the problems and the questions are placed by inserting the cards.

The typical flow chart is shown in Fig. 3.

Figure 3. Flow Chart for CAI

In the case of Figure 3, the pupil starts at a certain time, reads card 1, and after finishing card 2 goes to card 3 and so on. At card 8 there is an exersise, and the pupils must choose a button from 1 to 5. If the answer is correct (in this case no.3) then he can go to card 9. Whereas if he pressed button 4 for example, he should return to card 4 and go through cards 5,6 ...8, and try the question 8 again. If he again misses the correct answer, the indicator will direct him to card 81 or 90, on which "ASK TEACHER WHY" is displayed.

The questionanaires are placed to collect the rections of the pupils, whether they easily understand the sentences or not. At the final stage of the course, there is a NOTE to summarize the learning prosess.

The highschool chemistry curriculum for non-chemistry majors is called: "Inquiry into Matters", which consists of 9 Chapters and Experimental works (9 Subjects).

Because of the great deal of work required for the prepatation of the questions, the questionnaires and the programs, only three of the 9 chapters were treated for evaluation at this stage: Chapter 2

"Hydrogen", Chapter 5 "Carbon Compound—Ethanol" and Chapter 6 "Sulphur".

The data for the examination of Chapter 6 is shown below as an example of the evaluation of the text.

1) The number of pupils who had trouble at the check points. Card numbers where there is a question to check the pupil's understanding are as follows: 20, 26, 31, 35, 38, 106, 118, 126, 134. And the number of pupils who had trouble at these cards are shown in Table 1.

Table 1.

It can be said that cards 35 and 106 were the most difficult questions for the pupils. The former asked the oxydation numbers, the latter is the understanding of enthalpy. We will be rewriting these parts according to the data described above.

In Table 2 the total time vs.number of errors are shown. There is no particular corelation between time and errors, but it is interesting that the pupils who finished the course in a short time, made many mistakes.

Table 2.

There is a description of the names of minerals, a questionnaire was made to find out if the pupils knew these minerals, or if they had an opportunity to see or to handle them. However, 35 pupils out of 45 said that they never have seen such minerals. Through this result, we can say that the authors must show pictures of such minerals, if they really want to introduce them in highschool chemistry. Here is another example from the questionnaires. The heat capacity of sulphur was used without showing the theoretical background, which may be ignored by the pupils, unless the teacher has mentioned it. The questionnaire asked the pupils: "Do you have interest in the background of this number (Heat Capacity)?" and also "Will you try to calculate the Heat Capacity?"

Only half of the class has shown interest to think, and correct answers by 13. Among them only 5 said that "I am interested to examine the question further". Through this result, we decided to add more comments and details.

It should be mentioned that through the individual scores we could find the points to be clarified, and could rewite such parts without having the interpretations of the teachers who teach that class.

The instrument we have used here has difficulties to demonstrate experimental work. We have tried to develop a new type of machine which has two display screens and VTR system as well. This is called: BYNOCOM 210S, product of Nippon Micro Computer Co. (Fig. 4) However, because of lack of resolution of the screen, only Katakana were used for the display, therefore the demands from the text were projected through silides. The data for each pupil can be stored on floppy disks, and the teacher can summarize these disks afterwards. If the school would have a budget of ¥100,000;000 the CAI system in used now could be replaced by BYNOCOM 210S.

Figure 4. BYNOCOM 210S

4. Display of Chemical Phenomenon by Micro-Computer

4-1 Application for Dynamic Models of Micro-computer.

Chemical phenomena are basically dynamic, but, the traditional teaching methods use writing on a blackboard, or at best they use movies.

As was mentioned earlier, micro-computers are widely available today, and youngster are capable of handling them. So, program making is posible for gaduate students. The displays developed by them will be useful for undergaduate students or sometimes for highschool pupils. One example is the molecular vibration of the water molecule.

Figure 5. Molecular Vibrations-Water, Apple II Display

There are three normal vibrations for the water molecule, and the displays for each vibration were programmed by the following steps. Figure the size of hydrogen atoms and oxygen atoms used van der walls radii, the angle of the HOH bond is taken at 104.5°, and two pictures which correspond to extreme mode of the vibration are memorized in the computer. Then, these two pictures are superimposed at the timing of the frequency.

These displays were very attractive for the students and also for the highschool teachers.

4-2 Display of Probability.

The electron cloud model of the atoms are shown in textbook as dotted figures, however, the electron clouds are in fact the probabilities of finding the electron around the nucleus. The micro-computer display can be used for the electron densities using the probability functions as the time dependent variable.

The program was made by using the following steps. Using the random function generator, which is built into the machine (Apple II), Slater type wave functions of the Hydrogen atom, electron densities can be seen as dots from time to time; students in the indergraduate course could understand the meanings of probability quite well from this approach.

These pictures have also impressed students in the highschools and even the teachers.

Figure 6. Electron Density of Hydrogen Atom
—— Displays on Apple II ——

4-3 Displays with Conversations.

The examples described above are designed for viewing, however, if there were some conversation with the computer, it would be a more attractive challenge to the pupils.

Titration is one example. This item is in common use for acid-base balance, and we developed the simulation of necleolic titration on a micro-computer display.

The reason why we choose this display is as follows: experimental works are emphasized increasingly in chemical education, but, because of lack of labor, high costs and, more importantly, the lack of interest of the learners, the experiements are often ignored in the classroom. In addition to these, the discards (wastes resultant from the experiments) can not be desposed of in the city wastes. So, instead of the true experiments, the display can be used if the teacher wants to show the concept of the experiment.

The buret, the concentration of sodium hydroxide, and the volume of the acid in the flask is selected by random numbers on the screen. Titration can be carried out by the switch, and when the end point is reached, part of the flask changes its color to pale red, which is similar to the color of phenolphathlein.

After this experiment is finished, a conversation between the computer and the examinee begins. The questions and answers were prepared through the experiences of the CAI treatments mentioned above.

First, the computer asks the volume of the sodium hydroxide, and if it is correct, it then asks the normality of acid, using data just obtained. If the answer was wrong, the same experimental conditions will reappear on the screen, and the experiment is repeated. The calculation of the normality will be checked by the computer, if the examinee missed the calculations twice, the computer will tell him the correct method of calculation on the screen.

This program has been tested by several pupils, and we feel, we could improve the discussion sentences. Unfortunately, the conversation in this case was written in English, the difficulty is often caused by the lack of vocabulary rather than lack of chemical knowledge.

For undergraduate students, this display is not satisfactory, because it is too simple. So, we added an extra program to draw the titration curve for the experiment. This program is stored on a floppy disk, and the titration curve appears on the screen.

5 SUMMARY

As mentioned in the first part of this article, innovation in chemical education is very necessary, particularly these days. There are many ways to achieve this; the use of the Computer would be on of the best.

Although the usage of the computer was stimulated, there are many problems related to the used of the computer.

First: developing the programs is still not routine work.

Second: The question how to include the experimental work into the learning process has to be answered.

Third: The language problem. The Japanese language is not easy to display and many micro-computers have only the Roman alphabet.

Finally: If we want to have many terminals, the cost is too high. These are main difficulties connected with the introduction of CAI.

Generally speaking, the dissemination of the information on computer use will be most important for all educators, and the problem of copyright should be clarified in respect to the author of the program. If a Program Bank could be introduced through the activities of this Conference, people would greatly appreciate it.

TABLE. 1 NUMBER OF PUPILS WHO MADE MISTAKE(S) AT CERTAIN CARD(S)

CARD	NUMBER OF PUPILS	CARD	NUMBER OF PUPILS
20 → 61	6	106 → 61	17
20 → 81	1	106 → 81	5
26 → 61	6	106 → 91	1
31 → 61	8	118 → 61	5
31 → 83	2	118 → 82	2
35 → 61	18	126 → 61	9
35 → 84	5	126 → 84	1
35 → 94	2	134 → 61	10
38 → 61	7	134 → 85	1
38 → 85	3		
38 → 95	1		

61 ETC. ; REVIEW

80,90 ETC. ; ASK TEACHER WHY

CARD 35 ; OXIDATION NUMBER

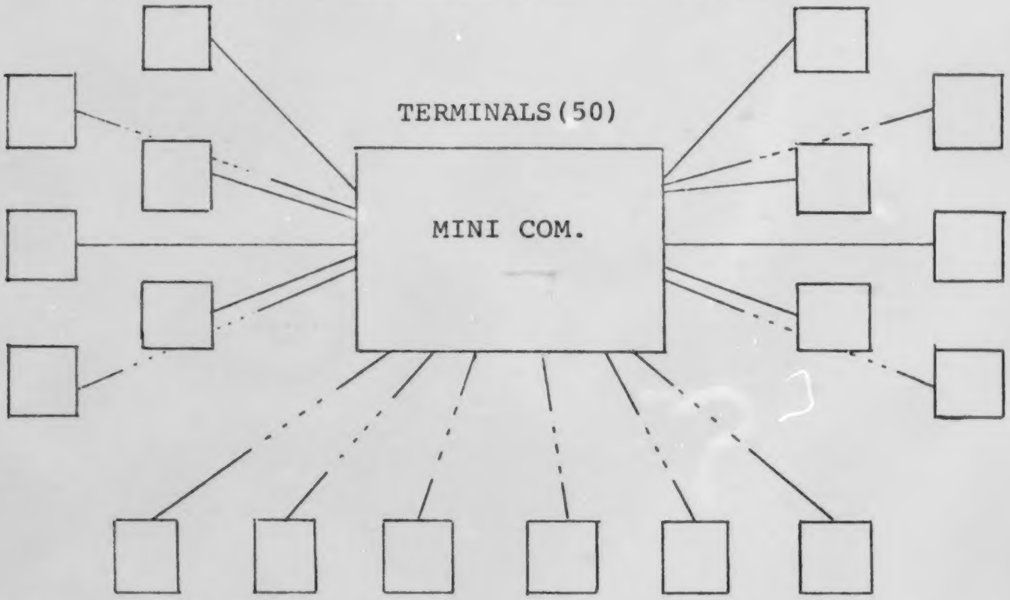
CARD 106 ; UNDERSTANDING OF THE ENTHALPY

TABLE. 2 NUMBER OF MISTAKES VS. LEARNING TIME

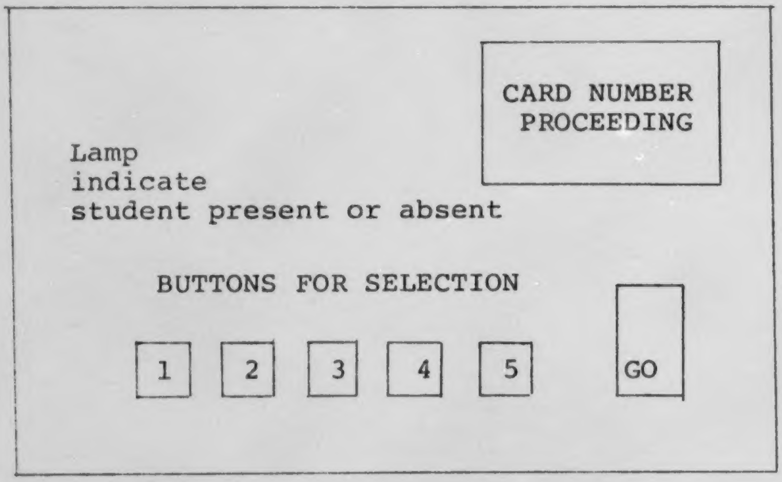
NUMBER OF MISTAKES	LEARNING TIME		
	AVERAGE	20 MINUTE LONGER	20 MINUTE SHORTER
0	2	3	1
1	6	4	4
2	4	1	2
3	6	1	1
4	1	0	2
5	0	0	0
6	2	0	0
7	1	2	0
8	1	0	1
TOTAL	23	11	10

Figure 1

CAI system at Koyamadai High School in Tokyo


TERMINALS(50)
MINI COM.

a) Diagram of CAI


CARD NUMBER
PROCEEDING
Lamp
indicate
student present or absent
BUTTONS FOR SELECTION
1
2
3
4
5
GO

b) Each Terminal Board

FIG. 2 PRINT-OUT OF THE INDIVIDUAL SCORE

```
SN= 2   SSEC= 287
  1(E  0: 5)      1(0  0:25)      2(0  0:12)      3(1  0:27)
  4(1  1:11)      5(1  0:57)      6(4  4:16)     81(4  0:45)
  7(4  0:52)      8(4  8:57)      9(4  0:23)     10(1  0:32)
 11(1  1:43)     12(2  0:56)     13(2  2:41)     14(2  3:39)
 15(2  0:57)     16(2  2: 2)     17(1  0:47)     18(1  1:24)
 19(1  1:41)     20(4  0:49)     21(C  2:13)     21(E  0:18)
 21(0  5:38)     22(2  1: 5)     23(5  3:19)     86(5  1:37)
 24(1  2: 2)     25(1  1:47)     26(4  1:14)     27(4  3:40)
 28(4  0:19)     29(2  1: 7)     30(2  1:23)     31(2  0:50)
 32(1  1:46)     33(1  1: 0)     34(1  1:56)     35(2  1:43)
 36(2  0:15)     47(2  3: 9)     32(1  0:21)     33(1  0: 9)
 34(1  0:13)     35(2  0:16)     36(2  0: 8)     92(3  1:10)
 32(1  0:14)     33(1  0:24)     34(1  0: 8)     35(2  0: 5)
 36(1  0:10)     37(1  1:33)     38(1  0:40)     39(1  0:58)
 48(3  0:13)     49(2  0:14)     50(4  0: 6)     40(3  0:43)
 41(3  0:59)     42(C  6:58)     42(E  0: 3)     42(0  0: 3)
 43(0  1:29)    254(0  0:26)      1(0  0:14)      2(0  0:34)
  3(2  0:30)      4(2  1:31)      5(1  1: 0)      6(1  0:30)
  7(1  0:16)      4(2  0:36)      5(2  0:19)      6(1  0:15)
  8(3  4: 0)      4(2  0: 8)      5(2  0: 4)      6(2  0: 5)
 10(0  1: 0)     11(0  0:22)     12(0  1:28)     13(0  1:54)
 14(2  1:14)     15(2  0:19)     17(2  1:34)     18(2  0:34)
 19(2  0:37)     20(2  3:11)     21(2  3:51)     22(2  0:20)
 26(3  0:14)     29(0  2:26)     30(0  0:22)     31(0  5:56)
 32(0  2:24)     33(2  1:34)     35(C  0:17)     35(E  0: 8)
 35(0  2:12)     36(2  6: 8)     40(2 26:16)     41(2  0:54)
 42(2  1:12)     43(2  0:43)     44(2  2:35)     45(2  0:38)
 46(2  0:14)     47(2  1: 9)     48(2  0:11)     41(2  0:29)
 42(2  0:25)     43(2  0:13)     44(2  0:23)     45(2  0:22)
 46(2  0: 7)     47(1  0:32)     51(C  0:30)     51(E  0: 3)
 51(0 23:31)     52(0 18: 9)    254(C 13:10)
TIME TOTAL= 3: 49: 38     STEPN=   113
```

FIG. 3 FLOW CHART FOR CAI

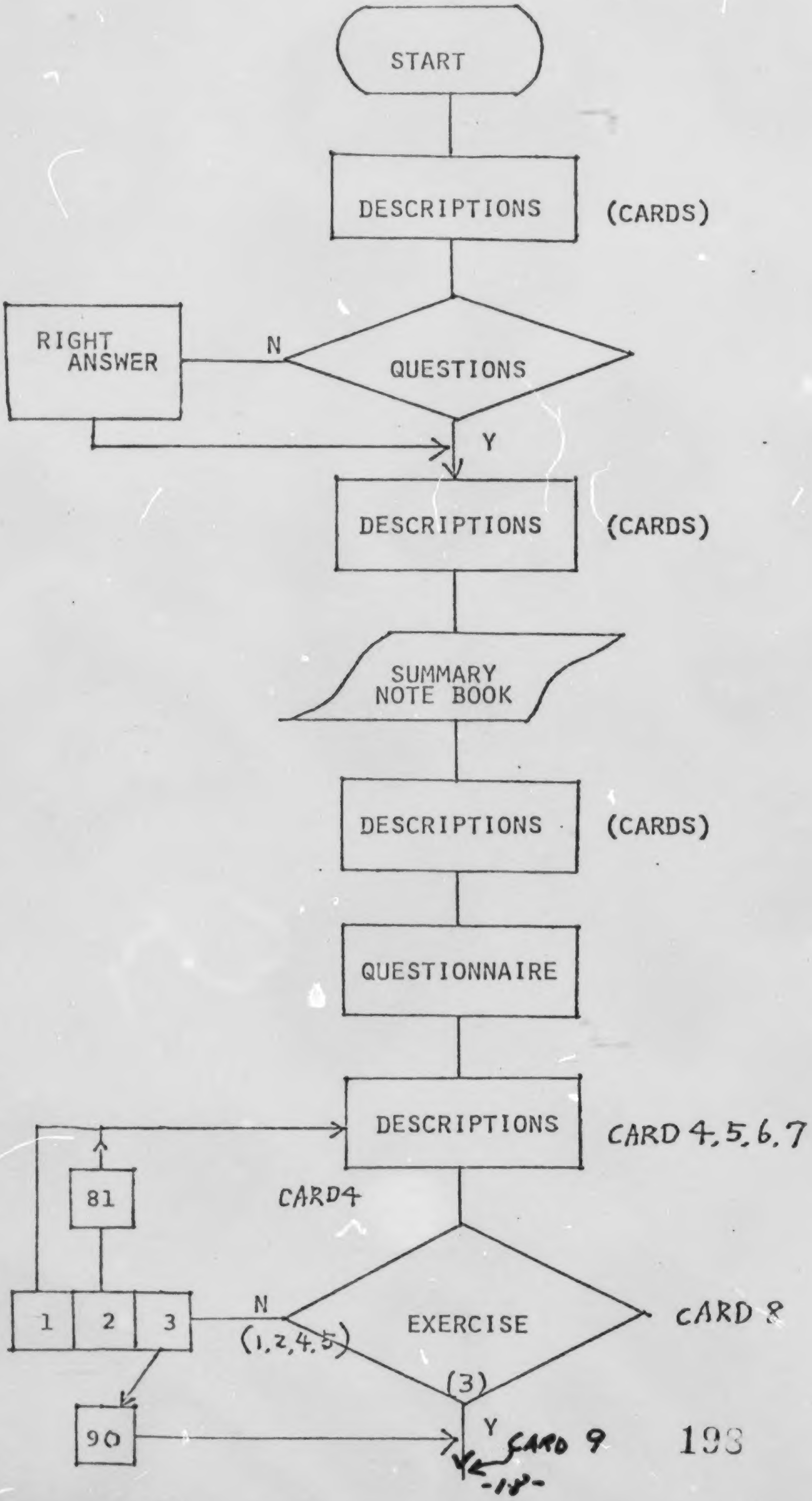
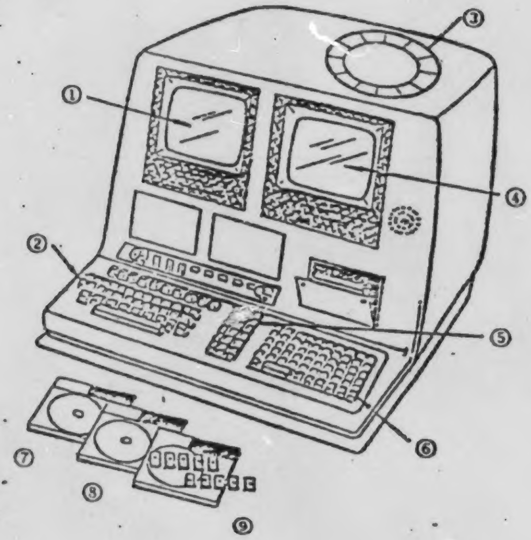

START
DESCRIPTIONS
(CARDS)
RIGHT ANSWER
N
QUESTIONS
Y
DESCRIPTIONS
(CARDS)
SUMMARY NOTE BOOK
DESCRIPTIONS
(CARDS)
QUESTIONNAIRE
DESCRIPTIONS
CARD 4,5,6,7
81
CARD4
1
2
3
N
(1,2,4,5)
EXERCISE
CARD 8
(3)
90
Y
CARD 9

Figure 4

Byno com 210S



①教師の指示	Treatments
②英　字	A. B. C……〕
③スライド	Slides
④本文，問，演習など	Cards display
⑤数　字	Number
⑥カナ文字	Katakana〕
⑦User System/AP program〕	
⑧Floppy disk	
⑨Farm Ware	

Byno Com 仕様

●寸　法：634×556×450mm
●重　量：35kg
●設置条件：AC100V±10%　50/60Hz
●動作温度：10°C～35°C

Figure 5

Molecular Vibrations——Water, Apple II Display

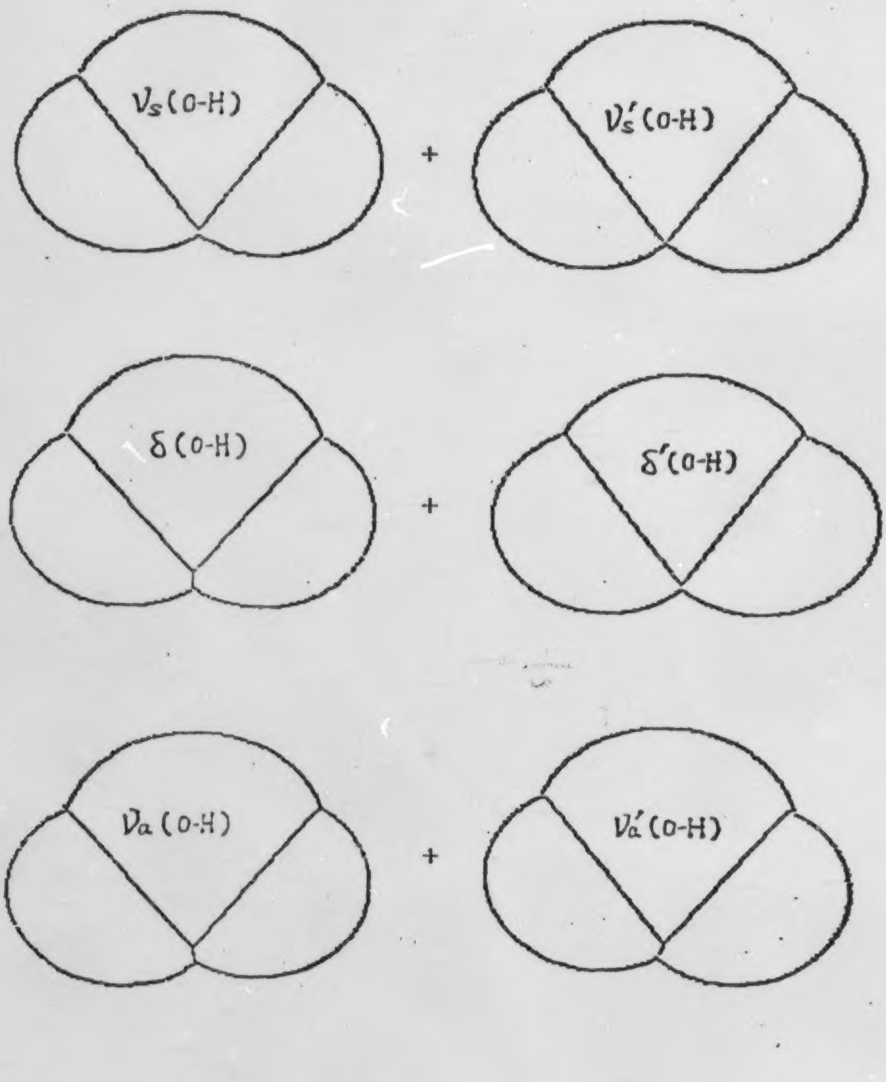
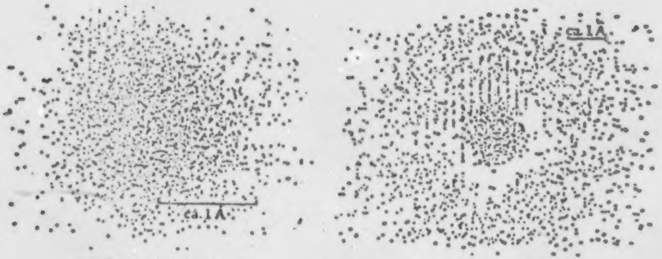

ν_s(O-H)
+
ν_s'(O-H)
δ(O-H)
+
δ'(O-H)
ν_a(O-H)
+
ν_a'(O-H)

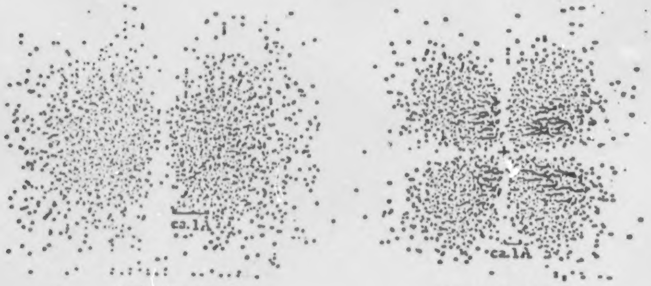
Figure 6

Electron Density of Hydrogen Atom

——Display or Apple II——



(1) Ψ^2 (1s) (2) Ψ^2 (2s)



(3) Ψ^2 (2p) (4) Ψ^2 ($3d_{xy}$)

Position Paper

Techniques and Technology

John W. Hill, University of Wisconsin-River Falls (see also position papers by Benfey, Shakhashiri, Shimozawa, Hosoya, and Moore).

In this paper, I will concentrate on the techniques of teaching chemistry to nonscience students and leave the technology to the others.

The premier technique is one of seduction: you have to get them to take the course, or you can't teach them anything. How do you get them to enroll in a chemistry course? Certainly you must make it interesting. You must also make it useful to the students in their daily lives as consumers, as citizens, and as conservators of our civilization.

How do you teach atomic structure and bonding to nonscience students? I find the Bohr atom and Lewis electron dot structures sufficient. Theories are tools. We should use those appropriate to our tasks. Using the quantum mechanical atom to teach a nonscience student a little chemistry is like killing the fly on the student's nose with a sledgehammer. And you get comparable results.

For chemical bonding, I emphasize covalent bonds. Two dots or a dash to represent an electron pair are quite sufficient. Indeed, dashes were used to indicate chemical bonds several years before the electron was discovered and for half a century before G. N. Lewis put forth his electronic theory of valence in 1916. Carbon forms four bonds, nitrogen three, oxygen two, and hydrogen one. We can build an awful lot of molecules from these simple concepts. Molecular models are extremely helpful in teaching chemistry to nonscience students.

A discussion of oxidation and reduction may be appropriate. We get energy for work and play by oxidizing foods. Energy for the maintenance of our way of life comes largely from the oxidation of fossil fuels. Plants make food by reducing carbon dioxide. Does that mean we must teach nonscience students to balance redox equations? Not at all. We can handle oxidation quite simply as the addition of oxygen (or removal of hydrogen). Reduction, obviously, is just the reverse.

A discussion of materials is extremely important (see also items 3 and 14). A reasonable model for the Earth's fossil fuel reserves is an orange. We may argue about how much juice there is in the orange, but the amount is obviously finite. To get a little juice out, we need only make a small hole. To get a lot of juice out, we must do great violence to the orange. Similarly, to get ever scarcer fossil fuels, we must cause ever greater environmental disruption.

The depletion of a fossil fuel can be demonstrated rather dramatically by burning a candle. Light one, partially hidden and ask the students how long it will last. (Our fossil fuel reserves are partially hidden, leading to varying estimates of how long they will last.) Now light the candle at both ends. How long will it burn? Obviously, only half as long. Now cut it in two and light all four ends. Repeat the process--in your imagination--until you have billions of tiny candles. Show how rapidly these would burn by throwing some lycopodium powder into a bunsen flame. Whoosh!! It's all gone.

The laws of thermodynamics can be approached--in simplified forms--in a course for nonscience students. These laws have a good deal to say about many of our problems and about some of our solutions. The first law says that energy is conserved in chemical reactions. Energy can be changed from one form to another. However, it is most important to note that some of the energy in any such conversion always winds up as heat. Consider the light bulb, a device for converting electrical energy to light energy. Only 1-10% of the energy is actually converted to light. The rest is waste heat. There is always some heat released in any energy transformation. Thermal pollution is an inevitable consequence of energy conversion.

The thermodynamic laws also state that there is a natural tendency from order to disorder. Again, we can reverse this trend. Again, the cost is energy. Take a new deck of cards. They are arranged in perfect order. Throw them out around the room. The cards can be put back in their former ordered state, but the cost is the expenditure of energy--bending, stooping, squatting, sorting.

In summary, then, we need to make use of numerous analogies and lecture demonstrations in teaching chemistry to nonscience students. But above all else, we must be enthusiastic about teaching chemistry to these our future citizens. If we aren't enthusiastic, our students surely won't be.

Position Paper

Educational Technology

Bassam Z. Shakashiri, University of Wisconsin, Madison

During the past twenty-five years the content of undergraduate chemistry courses has changed significantly. New chemical principles, techniques and facts have been incorporated into curricula. New curricula were designed for chemistry majors and for science majors. Modern instruments were introduced to all courses including introductory level courses. The changes in content reflect, in a modest way, the numerous advances in chemistry itself.

Also, during the past twenty-five years a substantial number of technological advances suitable for educational purposes were developed. Several chemical educators have tinkered with the traditional formats of instruction by incorporating audio-visual aids and computers into the design of undergraduate programs. Such tinkerings often met with questionable success partly because instructors did not effectively utilize the educational technologies and adapt them to the teaching-learning environment.

The effective utilization of educational technology depends on: availability of hardware, development of software, adaption of the teacher to the medium, and accessability to students. Examples of user-controlled educational technology are: programmed text, slide/tape unit, film strip projector, super-8 projector, audio cassette player, video tape or disk player, computer terminal, and electronic calculator.

At Wisconsin, several innovations have been incorporated into the general chemistry program. The major thrust is to individualize instruction. Audio cassette lessons, semi-programmed topical booklets, closed-circuit television and computer-managed instruction are designed to provide different levels and paces of learning to about 3000 students with varying degrees of ability and motivation. The use of CHEM TIPS provides each student with a reliable indicator of his progress; the feedback to the instructor identifies troublesome areas and enables him to provide each student with an individualized weekly assignment.

Instructional Television. Television equipment and programs are used primarily for pre-lab instruction. Over 30 videotapes have been prepared and used in introductory level courses and in some organic, analytical and physical chemistry courses. The videotapes are produced in the Chemistry Audio-Visual Production and Playback Center. Playbacks to laboratory and lecture rooms are scheduled for the beginning of the period or any other pre-scheduled time. The equipment is used frequently for "live" presentations in lecture hall to show close-ups of demonstrations. Also, television equipment is used by the staff for analysis and self-improvement of teaching techniques. Student and faculty reaction to the use of television as an instructional aid continues to be enthusiastic. The pre-lab segments are short (8-12 minutes) by design and have been found to increase the effectiveness and efficiency of laboratory instruction. The faculty and teaching assistants preview each videotape in their weekly staff meeting prior to use by students. Sometimes special television presentations are made for review purposes or for showing an educational program related to course material. For example, several NOVA programs related to nuclear chemistry have been used in introductory level courses. A special videotape dealing with significant figures, exponential notation and logarithms along with a handout is used during the first week of classes to help students review and learn simple mathematical concepts which are used in chemistry.

Audio-Tape Lessons in General Chemistry. A set of 34 audio-tape lessons have been developed and used in general chemistry courses at the University of Wisconsin-Madison and elsewhere. The lessons consist of audiocassettes and a Workbook with emphasis on drill in those areas of the general chemistry course that students have great difficulties with (i.e. quantitative thinking and calculations). The entire program is designed to simulate the situation in which an instructor is explaining introductory problems to an individual student. The aim is not to replace the instructor, but to allow the student to acquire sufficient knowledge so that when he or she confers with an instructor a meaningful and effective discussion of chemical phenomena and principles can take place. Both faculty and students have responded favorably to this instructional aid and have made invaluable suggestions to improve it. Students are encouraged to duplicate each of the audiotape lessons for individual use at home; the tapes are made available to students through the Freshman Chemistry Study Room and campus libraries and media centers.

CHEM TIPS. This computer-managed instructional system was described in J. Chem. Educ., 52, 588 (1975).

Lecture Demonstrations. Successful incorporation of demonstrations into lecture presentations is essential for stimulating student interest in chemistry and for provoking curiosity about chemical phenomena. Chemical demonstrations can be used as major vehicles for teaching specific concepts. The teacher's attitude and motivation in presenting chemistry plays a very important role. In fact, I believe that the single most important value of the lecture method of teaching is to convey the lecturer's attitude about chemistry.

I believe lecture demonstrations should be used to help focus attention on chemical behavior and to increase the student's knowledge and awareness of chemical systems. The use of demonstrations only as magic tricks should be discouraged. This approach explicitly means the teacher should be fully prepared to provide a valid explanation for each demonstration presented.

-23-

Position Paper
Educational Technologies
John W. Moore, Eastern Michigan University, Ypsilanti, MI

Success in teaching chemistry depends a great deal on the teacher's ability to induce or require students to participate actively in the learning process. When students are highly motivated and interested in or excited about a subject, getting them to participate actively is not much of a problem. Unfortunately the majority of non-science majors are less than excited about chemistry (or science in general), and many are even afraid of it. Consequently any tools that can be used to get such students actively involved ought to make substantial contributions to the learning process. Educational technologies are tools of that type.

Although I have had considerable experience with instructional films, audio tape-slide presentations, overlay transparencies for overhead projection, and textbook writing, and although all of these are excellent tools for helping students to learn, I would like to concentrate in this position paper on a single technology--computers. I think that computers offer far greater potential for involving students directly in the learning process than any other technology, primarily because computers require student responses to get something to happen, and as a consequence students can be drawn into dialogs that they eventually find to be quite rewarding.

An example of this is a computer game than an undergraduate student named John Estell wrote under my direction this past academic year. The game is called Chemical Dungeons, it is patterned after the famous Dungeons and Dragons computer game, and it involves a player in a mythical world where survival depends on chemical knowledge, plus a little imagination. In one situation the player is attacked by Medusa and must devise a way to avoid looking directly at her. Tollens' reagent plus glucose provides a silver mirror and the solution to the problem. When this program was available on a timesharing computer system so many students became interested in playing it that access had to be restricted to hours when the computer was not busy. Many students playing the game were not enrolled in a chemistry course, and some of them borrowed chemistry books from the library in order to try to figure out the problem situations presented by the computer.

In addition to interactive capabilities of the type just described, computers possess other attributes that make them excellent instructional tools. They can calculate rapidly and accurately, making the results rather than the equations of mathematical models available to students. Many computers, especially the tabletop or personal computers, have excellent graphics capabilities that allow results from calculations to be displayed in relatively concrete forms, including animation of molecular mechanisms corresponding to observable phenomena. Computers can simulate a wide variety of phenomena, allowing students to become involved in situations that would otherwise tbe too complicated, too dangerous, too fast, too slow, or too expensive for them to experience directly. Finally, and very importantly, the cost/performance ratio for computers has been dropping very rapidly and can be expected to continue to drop, making these versatile machines available to a continually broadening audience.

Computers can also be distinguished from other instructional technologies because computers are important tools of chemical research in a way that film, video tape, programmed instruction, and so forth are not. Just as we teach about other research tools, instruments, for example, we need also to teach about computers. Unlike most instruments, however, the same computers that are being used for advanced research can be made directly available to students. What better way to teach about computers than by having students interact with computers and learn from them?

There are a variety of ways that computers can be incorporated into courses for non-science majors. One very important one is to provide remedial computer-aided instruction materials aimed at assuring that all students in the course will have adequate background, both in chemistry and mathematics. Computer programs for this purpose can be simple drill-and-practice exercise, which are relatively easy to write. Many of these are already available for a variety of microcomputers, such as the TRS-80, Apple, and PET, as well as for timesharing systems. Programs of this sort can be obtained from authors of Bits and Pieces articles in the Computer Series in the Journal of Chemical Education, or they can be purchased from commercial software suppliers. While these programs generally do not make use of the full capability of most microcomputers, students can often achieve far more rote learning during a 20 or 30 minute interaction with a computer than they would in an hour or two or normal study.

A second area where computers can be used very effectively, especially in large classes, involves preparation of tests and homework assignments, scoring of those assignments, and class record keeping. Programs that carry out these functions are available from several sources, and for a variety of course levels. Some of them generate numerical data, providing each student with a unique set of numbers that the student must analyze on his or her own. Other programs provide for storage and retrieval of large numbers of test questions, from which unique but equivalent tests can be constructed. A variation on this theme is to have the computer itself generate test questions by random selection of phrases and/or numbers that are then inserted into a stem question. Computer-assisted test construction of both types is described in more detail in J. Chem. Educ., **58**, 177 (1981). Finally, the computer's ability to handle large quantities of information rapidly and accurately make it ideal for course record keeping. Computer-managed instruction systems range from those that simply keep records for the instructor to ones that regularly provide students with evaluations of their progress and suggestions for further study.

The computer's greatest potential for improving chemistry instruction is probably in the area of simulation, especially when medium to high resolution graphics displays are available. Computers can be used for pre-laboratory instruction, where setting up and operating laboratory equipment is simulated. Computers can simulate instruments, providing spectra and other types of output that students are then expected to work with. Computers can simulate the microscopic world giving us pictures of electrons, atoms, or molecules, both static and in motion. Finally computers can simulate the real world, giving students vicarious experience with industrial processes, control of environmental pollution, design and testing of drugs, social, economic, and political implications of chemical knowledge, and many other areas. Such experience would be difficult or impossible to achieve in any other way.

Computer programs of the type described in the previous paragraph are more difficult to write and require broader knowledge on the part of their authors than do those described earlier. Consequently the number of good ones available is not yet large, but as they become available such programs will have profound positive effects on students' interest, motivation, and achievement in chemistry. Strong support should be provided for the development, testing, and adoption of these and other types of computer programs for introductory chemistry courses.

Position Paper

Evaluations and Testing Instruments

Anna J. Harrison, Mount Holyoke College
(see also position papers by: Gardner, Shimozawa)

That which is tested and how evaluations are made defines to the student the goals of the course. If the tests require formulas, equations and calculations, the student will see the course as formulas, equations and calculations and very little more. I have come to suspect that the events, which led to the unpopular status of science courses, had to do with testing primarily that which can be most easily tested, being somewhat arrogant about the quantity of material dished out and being even more arrogant about the scores required for a creditable grade.

The process of evaluation must be consistent with the goals of the course. We expect our students to write and at least thirty percent of every major written is an essay question. About thirty percent requires calculations and the remainder is made up of short answer questions. The student has a number of options in each of these three segments. The goal is to provide the student the opportunity to demonstrate to herself or himself and also to the instructor what she or he has accomplished.

A pass/fail option seems appropriate in institutions which have that option. Larger institutions would have to devise other mechanisms to achieve the same goal. The goal is, I believe, appropriate to all science education for the general student.

POSITION PAPER

What kinds of evaluation and testing instruments should be used in chemistry courses for the non-major student?

Marjorie Gardner
Department of Chemistry
University of Maryland
College Park, MD 20742

Perhaps it is best to keep formal testing to a minimum--to run the course on a pass/fail option with very limited testing or perhaps none; only the evaluation of a project or paper associated with the course. The theory behind this approach is that a student should be able to enroll in a chemistry course for non-majors without severe threat and to relax, explore, enjoy and learn. Unfortunately, the fact seems to be that this does not work well in practice. Students are under pressure each semester to successfully complete 15 to 18 semester hours of credit. They are human; they wish to survive and to do as well as possible scholastically. Therefore, they distribute their time and efforts where the pressures are the greatest and the evaluation systems most demanding. That is one of the problems we face in trying to define not only the content but the teaching and assessment style.

Evaluation and testing instruments have other uses and purposes beyond assessment. They also can serve as powerful means of clearly defining the academic goals of a course. Our challenge is to learn how to evaluate creatively in a mode that not only assesses achievement but also defines objectives and, in fact, serves as an instrument of instruction.

How can we do this creatively? People, very dedicated and talented people, have tried to find the answer to this question over decades of time and the answer is still not known. If we want these students to think, we must test for thinking. If we want them to be able to organize and express their ideas, they must have opportunity to write and to speak about concepts and issues in chemistry. Success requires practice; a one shot effort has little effect. But essay questions and oral presentations pose their own problems since (a) very large amounts of grading time are required, (b) students must receive feedback if such exercises are to be of value to them, (c) time must be allocated for oral presentations either to the class or to the instructor to make this system work. There are other pitfalls. Members of the class aren't really interested in hearing from their peers; they registered to learn from their professor. The professor has not enough office hours in a day to hear and evaluate individual oral presentations. Teaching assistants may be helpful, but are often not experienced enough or committed enough to provide the analysis and support students need to make written and oral presentations fruitful.

How can we give them the experience and test their progress in organizing and expressing ideas effectively?

Another mode of evaluation that should be explored further is the use of the term paper. A paper that stimulates and demands excellence from the students, that requires library work, reading in current and classical literature, organization of ideas, development of personal positions and presentation of these in a form that exhibits fluent writing, good grammar, appropriate illustrations and neatness should all be requirements for such a paper or project. Illustrations often evoke creativity from students and can be used as a measure of individuality and effort.

Use of electronic response systems for immediate feedback in the classroom should be explored further. The programming and use of computers to permit a wide array of testing items at different levels, on different content, and to free the instructor for teaching rather than testing, must be explored further, too. In fact, the whole micro-electronics revolution has had little or no impact yet on evaluation and testing. But the potential exists and must be explored.

Position Paper

Interdisciplinary Programs

Anna J. Harrison, Mount Holyoke College
(see also position papers by: Benfey, Ramette, Saito, Shiba
as well as Topic 8, Case Studies and Environmental Systems)

An individual chemist can, I believe, develop a course in chemistry that is interdisciplinary in orientation. To develop a truly interdisciplinary course in this country at this time is probably not an appropriate undertaking for an individual. Scientists drawn from the various disciplines should be involved.

In any case, disciplinary or interdisciplinary, the courses, appropriate for the general student, should be orchestrated - built about a theme. Such an orchestrated course can be either disciplinary or interdisciplinary in nature. I believe that a significant introductory disciplinary course can be developed for one semester, an introductory interdisciplinary course would require longer. A very significant upper level interdisciplinary course could be developed for one semester.

None of the questions directly address goals and it is my intent to put together a position paper on goals.

Position Paper

Interdisciplinary programs

Richard W. Ramette, Carleton College

To paraphrase Dennis Meadows (co-author of "The Limits to Growth") we should try to be "adisciplinary", not merely interdisciplinary. He takes the view that, when we go into the world, we don't see "disciplines" laying around but rather "stuff" that needs to be studied by all possible techniques and with many simultaneous viewpoints. I like Joel Hildebrand's concept of the so-called "scientific method": "To be successful in unlocking the doors concealing nature's secrets, a person must have ingenuity. If he does not have the key for the lock, he must not hesitate to try to pick it, to climb in a window, or even to kick in a panel. If he succeeds, it is more by ingenuity and determination than by method."

It would be interesting to design an introductory college science course for non-science majors by focusing on the nature and behavior of a local lake or stream. I would like to see how we could make use of physics (the importance of heat, light, velocity, mechanics), biology (photosynthesis, growth, population changes, identification of species) and chemistry (dissolved oxygen, minerals, pollutants, etc.) to try to give the students a holistic view of a situation they normally would take for granted.

A special problem with interdisciplinary approaches is the lack of breadth in the teachers ourselves! Such courses cannot be managed by teachers who are not willing to get outside their disciplines and make a strong professional commitment. This is not an easy decision, of course, and I suspect that interdisciplinary courses will not become as important as they should.

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Position Paper

Science-Economic-Political Interface.
Instruction in Chemistry for the Non-Major Student.

Robert C. Brasted, University of Minnesota

(see also position papers by: Harrison, Gardner, Shiba

It is possible that there will be greater variance in the treatment of this topic than any that are part of this Seminar. In the opinion of the writer, the capacity of our citizenry (or those of any country) to deal intelligently with the "Interface" problem would be the reason for non-major science instruction in our college programs. There is no particular reason for our limiting this kind of instruction to the non-major.

The obvious question is how should material that would serve as background for sound judgment be presented? At the expense of redundancy:

> "Can or should we as chemistry teachers alert students at this level of sophistication to the importance of international dependence on, for instance, raw materials? There is no reason to limit our discussion to fossil fuels. Do we have the time, expertise, or even the prerogative to discuss the oftentimes little appreciated factors in international relations, such as bargaining in the chemical market from a position of weakness? Thus, can we teach enough of industrial chemical processes for our students to appreciate the implications in our daily lives of one nation cornering a market in such areas as: platinum metals, bauxite, cobalt, iron ore, to mention many species of chemical interest?"

Several of these, plus a few closely related ones, are discussed using the writer's own attempts to provide the intellectual tools to comprehend, though oftentimes in only a simplistic way, the problem of the Interface.

The dependence of both our countries on fossil fuels is such that the student should have little problem relating to in international dimensions. It should not be difficult to take advantage of issues that dominate the news to interest the student in a chemical phenomena. In addition to the thermal aspects of energy it would seem that the teacher would have an obligation to discuss the correlating factors of by-products, the environmental impact that might depend upon the source of the energy (since certain of the fossil fuels are more prone to an adverse effect on the atmosphere than others), the geographic and demographic nature of the suppliers of many forms of fossil fuels for both our countries. Obviously, we do not have the time, or in many cases, the expertise to dwell long upon such relationships, but certainly a large part of the battle is won in alerting the student to the importance to international affairs as they relate to chemistry. The writer is fearful that there will be no other part of the college curricula that can alert a student to the bargaining power of a nation in the raw material sense. If a country has little to offer but needs much, the citizenry will pay dearly at the negotiation table, perhaps paying with their freedom. There may be a fine line that we as teachers must tread; chemistry on the one side and politics (or economic theory) on the other. It seems very reasonable and very real that students be aware of the ever growing dependence of one discipline upon another.

Japan and the United States are not alone in the international dimension of ecology. The waters (oceans, lakes, and streams) and the air are no respectors of borders. One country's pollution easily and quickly can be another country's problem. There are many parts of our so-called non-major course, lecture and laboratory, where we will have the opportunity to inform and instruct in the production of such pollutants as the oxides of sulfur, nitrogen, carbon; fluorides, heavy metals, sulfides, amongst others. Why not take a few moments to point to the responsibilities that we have to our neighbors?

We all certainly devote a non-trivial amount of time in our teaching to the subject of water. The just mentioned instruction relevant to the atmosphere of acid oxides which ultimately result in the lowering of the pH of our natural waters make an understandable application of pedantic and probably dull subject of classical acid and base theory to a very real situation. The writer attempted over several years to use the Journal of Chemical Education to stress this approach in the "Vignettes" series. Professors Campbell and Plumb produced other series with similar ultimate objectives.

No effort in this short paper has been made to be exhaustive. An obvious question suggests itself: "Are we capable as science teachers or knowledgeable enough to narrow this gap between pure science and the world conditions, both economic and political?" If we are not, it is difficult to identify any group in a college faculty who would be more capable.

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POSITION PAPER

Should a course for non-majors include a science-economics-political interface?

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It is neither realistic nor academically wise for chemists to ignore the real world. Science does have economic and political overtones. They cannot and should not be completely ignored in the chemistry classroom. However, there are severe problems associated with trying to develop economic and political interfaces. These include our lack of knowledge and expertise in these social science areas, the difficulty in determining what the delicate balance should be, and the problem of how to best use the brief time available to us for such a course. I believe that the answer lies in teaching CHEMISTRY but in using the relevant (as opposed to the classical) examples and anecdotes to do so.

As we teach catalysis, some acid-base chemistry, or the Haber Process, for examples, we can use interesting anecdotes that relate the chemistry being taught to the news of the day, the importance of the product, something of industrial development and we can use humor and history to enliven the presentation of the facts, concepts and theories involved. Some excellent materials are now available. For example, C&EN publishes profile data on petrochemicals and other high volume use compounds; these provide up-to-date information on the production, the use, import/export data, market trends, etc. Articles from C&EN, Science'81, Sci-Quest, etc. on topics such as acid rain, planetary chemistry, new polymers, etc. can be utilized to bring an economic/political interface into these courses within the context of chemistry. Such readings can be distributed to the students or incorporated into lecture anecdotes.

An interesting example from this week's news would appeal to the non-science student since they, like nearly all human beings, are interested in the beautiful, precious gem, the diamond. A new diamond mine, with potentially a larger output than South Africa's, has been discovered in Northwest Australia. Now, who controls the production and distribution of diamonds in the world? What effect will this have on the gem-sale economy or on the industrial use of diamonds? What is a diamond and how is it formed? A good lead into carbon chemistry or the carbon cycle, perhaps?

I'd be very much in favor of bringing the most current examples from the newspaper, popular magazines, the television news and features, etc. into the course for non-chemistry majors as long as the material helps strengthen and enhance the chemistry that is being taught. The use of good films and videotapes that have some social science flavor is certainly appropriate providing the focus is on conceptual chemistry and a search for understanding.

Position Paper

Scientific, social, economic and Political interfaces

Anna J. Harrison, Mount Holyoke College

(see also position papers by: Brasted, Gardner, Shiba

All students, regardless of whether they become scientists or not, should have the opportunity to develop an understanding of the relationship of science and technology to the social, economic and political matrix of which science and technology are a part.

Here is a list of premises which I believe are worthy of exploration with students. The specific framework within which they are explored is of little consequence.

1. The direction and the rate of the extension of scientific knowledge are to a large degree controlled by social, economic and political processes.

   The direction and the rate of development of technology are to a large degree controlled by social, economic and political processes.

2. Science and technology are in the business of creating technological options.

   The support of research with public monies is an act of faith that on the average research leads to innovations that serve the public good.

3. Every technological innovation, regardless of how great its positive contribution to society also has negative impact on some subset of society and in some time frame.

   The subset of society that is the recipient of the benefits may not be the subset of society that is the recipient of the negative impacts.

   The time frame of the benefits may not coincide with the time frame of the negative impacts.

4. Decisions concerning the quality of human health and the environment are the prerogative of the public and the surrogates of the public.

   Decisions should be consistent with the mores of society.

5. Both technological capabilities and the mores of society change with time.

For a class to explore and list possible benefits and possible negative impacts is comparatively easy - and safe. It is also comparatively easy to discuss how difficult it is to quantify either the benefits and/or the risks.

To make the decision to regulate (including the decision to ban) or to promote requires a value judgment. It is at this point those of us who are scientists cannot speak as scientists. In matters related to value judgments, we can only speak as individual members of the public. It is at this point we are participating in the democratic process and we must respect the value judgments of all others - including our students.

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Environmental Problems in General

Abstract

Michinori Ōki

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The basic problem in environmental issues is to recognize, both by chemists and by general public, that human being is made of materials and reacts on being given impact by external stimuli. The point is the handling of materials. Chlorine is a poisonous gas. Therefore it was used as a chemical weapon in the World War I. But it is not fair to teach merely that chlorine is toxic and harmful beacuse it is indispensable in modern life as a germicide. There was an instance of drug hazard, called sumon disease. It was caused by overdosing of quinoform, which had been used as a binding medicine. Chemistry has been a discipline which trains how safely a man can handle a hazardous material; dynamite is a good example. We must teach and explore in what way we can handle chemicals safely.

The concept of purity is also important. We say it is clean when we cannot find foreign maerials. Chemicals are pure when no impurity is found. Therefore the purity depends on the level of analysis. With aqueous sodium iodide, it is possible to detect silver ion in a solution that gives negative test when aqueous sodium chloride is used. The method of analysis must be a concern when we admit that a material may not be harmful up to a certain

dose.

Here we come to another point that we usually teach only a chemical reaction which occurs to a detectable amount and, in many cases, only a major reaction. Nitrogen had been taught to be an inert gas. But its reactivity is, though low, high enough to produce a tiny amount of nitrogen oxides in furnaces. And this nitrogen oxide is the origin of air polution today. In the same sense, we may better teach that carbon monoxide is always formed, though a little, when organic materials burn.

The concept of conservation of element is fundamental in chemistry. It has been taught in chemistry courses but does not seem to have become an unforgettable memory. A typical example is Minamata disease. Mercury salts were used as catalyst for hydration of acetylene. No chemists thought of the poisonous element, mercury, would come back to human being some days after it had been drained. But elements are unperishable and mercury came back to people via fish and shells to cause disasters. On this stand point, it is an essential problem to teach what is a clever way of discarding things, not only heavy metals but also pepars, plastics and aluminum cans. Wise disposal will not only save natural resources but also will save energy to produce the unnatural materials to end up in preventing energy pollution.

Correct answer to the environmental problems has not been found. Therefore it is not proper to call it teaching. It may be a good idea for a professor to discuss the problem with students, by behaving as if he/she is a student. This may be embarassing but has been proposed in CBA and CHEM Study programs. Concern is the balance between economy and preventing pollution. We may rely upon technology which prevents pollution, if we are prepared to pay suitable amount of money. There can be a wide variety of thoughts among people.

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Environmental Problems in General

Michinori Ōki
Department of Chemistry, Faculty of Science,
The University of Tokyo, Tokyo 113, Japan

1. Materials and Human Being

The basic problem in environmental issues is to recognize, both by chemists and by general public, that human being is made of materials and reacts on being given impact by external stimuli. The man inhales air and uses oxygen to get energy which is needed for activities, both internal and external. As a result, carbon dioxide and water vapor are discharged to the environment. He takes foods and uses what are needed for maintaining his growth and/or body. The rest of them is discharged. As a result of metabolism, various wastes are produced and are discharged. Other chemicals have chances to be inhaled or to be taken with foods. This is a great concern of general public. They fear that a compound may harm their health or may cause cancer. The author believes that here is a role which chemical education can play.

Chlorine is known to be a toxic gas. It was used as a war gas in World War I. But it is not realistic to merely teach that chlorine is toxic and should not be used in daily life. Chlorine is a simple body (element) which is indispensable in daily life because it is used as a germicide in city water.

Morphine is another example. It is well known how harmful this compound is, when chemists teach that it is a main constituent of heroin. But it is also used as a local anesthetic in medical care. We can cite another sad story that a drug called chinoform caused paralysis of many people which led to death of some. The drug had been used as a binding medicine for more than 50 years. Why this kind of tragedy could happen? The answer is overdosing.

The above examples clearly show that a substance may be used both as a poison and as a useful material. The critical point is a dose. Anything which is very useful may be harmful when it is used in a great amount. Unfortunately, there have been not enough research works done to determine the limit of the amount of a compound used in the past. The only thing done in the past is to determine whether a compound is harmful by giving animals in doses which we do not take that much in daily life. This of course gives absurd results very often. It is not hard to find that kind of examples.

Hydrogen peroxide had been used for bleaching bean curd and fish products. But as a result of giving grams of this compound to mice, carcinogenic activity was found. When the result was publicized, our government had to ban the use of hydrogen peroxide in food industry, although most of it will be decomposed before the time when the food is taken. Benz[a]-pyrene is a strongly carcinogenic material. Therefore it is understandable that people wish to avoid it as completely as possible. But issues which occurred in Japan were absurd in a sense. Ajinomoto made from acrylonitrile contained a tiny amount of benz[a]pyrene. Single cell protein contained also a minute amount of that carcinogen. Then people began to attack on the production of these materials, although the carcinogen found in the air is much more than in those foods. Research on the maximum tolerable dose is apparently important and is urgently needed.

The results of this shortcoming in handling chemical substances are that general public feels that chemistry is hazardous. But mishandling of any matter can cause harm. High voltage electricity may kill a man, although electricity is very useful. Water is indispensable for organisms including human being. Yet it can drown a man if it is misused. Chemistry is a discipline in which the proper way of handling chemicals is taught. A good example is glycerol nitrate. It is an explosive, dangerous material. But if it is adsorbed on kieselguhr, then the handling of it is much easier and it is used as dynamite which is very useful for construction of dams and canals and for mining useful materials. Ways of teaching this kind of skills must be explored.

Indeed there are some examples in which traditional foods are taken without fears. Since the discovery of Minamata disease, people abhor mercury. One day tuna was reported to contain mercury to some extent. Newspapers suspected that pollution by chemical industires caused contamination of sea water with mercury. But fortunately, there was a sample of tuna which was fished long time ago. Analysis of the sample showed that the old tuna contained as much mercury as tuna of today. Thus tuna is still favorite fish of Japanese. A biochemist reported that when fish is baked, there is formed a strongly carcinogenic substance. Yet Japanese do not avoid baked fish even today. These episodes indicate that people become emotional when they are informed mishaps but are convinced if they are properly taught. Chemicals have short history. This seems to be the main reason why people fear those. A large amount of data is necessary to convince people that a chemical substance is safe up to a certain dose.

The rate of discharge of a chemical is also important and should be taught in a chemistry course. There is a case of mishap caused by polychlorinated biphenyls (PCB). These compounds are stable chemically: that means they are not deteriorated easily in air or in water. They are oil-soluble but are not converted to water-soluble materials. This causes accumulation in body and at the extreme PCB taken in tiny amounts may finally cause the mishap which is known as a disease of Kanemi oil. If PCB is metabolized to water-soluble materials, this kind of cases may not have happened.

There is a good example of this sort. Benzene was used as a solvent of the glue for rubber. A blood test was performed for those who used to use this glue to find that there were many who showed appreciable decrease in the number of leucocytes from the normal. The decrease was apparently caused by the use of benzene. Therefore toluene was used in place of benzene in the glue of rubber. We must confess that at the time many chemists thought that toluene would cause same trouble because of the similarity of the compound with benzene: it could be consolation but not a solution. But as a matter of fact, the decrease in the number of leucocytes subsided. This astonishing result from the view of chemists must be caused by the fact that toluene is much more easily oxidized to a water-soluble material than benzene to be discharged. In this case a methyl group is playing a very important role.

We should not forget the ability of human being: that is the remedy of or recovery from damage. If there is not such ability even the sun light can perish the mankind because important nucleic bases are known to undergo photochemical reactions. Therefore a tiny amount of a toxic material is not really a poison. This may be connected to the maximum tolerable dose that is worthy of discussion in chemistry courses.

2. Limit of Detection and Its Effect on the Environment

We usually say that a compound is pure if an impurity is not detected by available means. But general public in, at least, Japan does **believe** that there is a really pure substance such as a single crystal made of only one kind of atoms. Japanese people are philosophical and not practical in a sense. Thus it is necessary to show students that there is not a really pure substance. For introducing this kind of concept, we should like to approach experimentally.

It is possible to show that an aqueous solution containing silver nitrate produces precipitate when aqueous sodium chloride is added. In other words, we can say that the water contained an impurity because we could detect the latter. However, if we dilute the solution with water, the precipitate of silver chloride may not be formed because the concentration of silver ion is too low. We ask students whether they think this water is pure. They are puzzled but usually say that the water is still impure because it contains silver nitrate to some extent. Then we can show them by adding aqueous sodium iodide that there really is present silver ion. But, by further dilution, we reach water which does not give precipitate on addition of aqueous sodium iodide. We declare that water is pure but the statement is confusing at least to Japanese students.

We can use another example. Because of the impact given by IPS, it is very common in Japan to determine purity by measuring melting points in junior high schools. If students find a flat place in a temperature-time diagram with continuous heating from outside, the substance is defined pure. But it is very easy to detect impurities in those compounds which give short ranges of melting points. Thin layer chromatography is especially good for this purpose. Here the students may be impressed by finding impurities from what they thought pure. We can teach them that, when we say it is pure, we also have to state at what level we discuss.

Experiences of washing may be cited when we discuss this concept as well. When our hands are stained by black machine oil, we say the hands are not clean because we can see black spots and we feel something sticky. When we wash hands with the aid of soap, the black spots and the sticky feeling may be removed. Then we say the hands are clean. It is not a problem whether there is still some oil left if we examine by FT-IR spectroscopy.

The concept is connected to the pollution problem. If we dilute a solution containing chemicals with large enough quantity of water, we say that the drain is clean. But the fact that the solute, although diluted, has not disappeared should be kept in mind. It is especially so in Japan, because we have been accustomed to that, if we cannot find dirt around us, we say things are clean. It was quite common some years ago that dirt was sweeped out with a broom from a house.

In connection with purity, we must mention that Japanese are rather weak with numbers. If a certain number is shown, average Japanese think that it is to be believed. The origin is probably money. If we discuss the amount of money, the account must be correct whatever places of numbers may be. If an officer of the Board of Auditors comes to our university, he will be concerned with an error of one yen out of 1,000,000,000 yens. This means we have to have 10 significant numbers. It is of course impossible in usual scientific treatments. We must teach students that beyond a certain place, the figure is not accurate any more. It may be a good idea to tell students what happened in the results obtained in leading analytical laboratories. National Bureau of Standards asks various laboratories to analyze standard samples. The results can differ by a factor of 1000 if the constituent in question is present in really a small amount. Teaching how to read numbers is one of the very basic points in chemistry courses in Japan.

3. Interaction between the Matter and Natural Environment

Apparently human being is involved in a system of circulation of matters or atoms (elements) on the earth. We have pointed out that Japanese used to think clean if they can not see dirt around them. There is a term "drain with water". This is to forget hostage or sad memory after a ceremony or a certain occasion. The expression is quite often used. Therefore this kind of thought is common to Japanese people. As an extension of this thought, nobody doubted that the inside of factories could be cleaned by washing with water. However, nobody cared what will happen after the dirt was drained. One of the first pollution cases occurred in Shizuoka Prefecture where a number of waste-paper recycling factories was located. In those factories, vast amount of water was used to reuse the waste-paper. Thanks to the water used, we could get paper of good quality again. However, a problem took place. That is the accumulation of dirts drained from the factories in the sea. Although the sea is a part of Pacific Ocean, the amount of dirt discharged with water was too much. The dirt accumulated and caused various undesirable phenomena such as accumulation of heavy metals, formation of methane, disagreeable oder, etc. As a result of these, even deformed fish was found. The fishermen around the area were furious of course and this anger connected to the public movement of antipollution.

We teach in chemistry that element is not perishable. But even chemists seemed to forget this very basic concept of chemistry. An example is the Minamata disease. Mercury salts are good catalysts for hydration of acetylene. The catalyst had been used for the production of acetaldehyde and drained to the sea. Probably the people in the factory thought that the inside was clean but did not think of what would happen if mercury,an element which forms poisonous compounds, was not perished. Mercury did not perish indeed and was taken up into shells and fish around the Minamata area via microorganisms. Those animals were eaten by people around the area and became the origin of the Minamata disease.

The above two cases teach us that we must think of the earth as a whole rather than of the place around us only. Therefore the citizens of the next generation must live with comprehensive consideration. The important point is that people realize that they can be the origin of pollution. Waste polymers and waste cans are great problems in our country. We cannot rely solely on the good will of a few volunteers to clean the environment. Here is a role that chemical education can play, though it may not necessarily be concerned with university education.

In this connection, it may be worthwhile to teach students that, even though an amount of waste discarded by a single person may be negligible, the amount can be vast if vast number of people did. There is a sentence which is used by a geophysicist: zero multiplied by an infinitely large number gives a finite number. Although this expression is not correct mathematically, it may be useful in teaching environmental problems.

One of the examples of this sort is the chemical reaction which occurs hardly but is important because it occurs in vast amount. Nitrogen had been thought to be inert and used to fill electric lamps. It may be good enough to teach primary school children in that way even today. But in colleges, at least, the fact that a tiny amount of nitrogen oxides is formed when organic materials are burnt in the air must be taught: these oxides are origins of air pollution. This activity of burning of organic materials takes place not only in large factories but also in engines of cars and in kitchens. Therefore general public is responsible also to polluting the air.

Formation of carbon monoxide in burning is another example. In classical chemistry courses, formation of carbon dioxide is discussed together with reduction of carbon dioxide with carbon to carbon monoxide. However, the formation of tiny amount of carbon monoxide in normal burning is usually neglected in the classical chemistry course. Since an appreciable number of Japanese is killed by carbon monoxide which is formed by incomplete burning, we ought to teach this problem in connection with the air pollution by burning organic materials.

4. Ways of Avoiding Pollution

The word "balance in nature" is often used. We may teach the difference between equilibrium and steady state at this point. As human being has an ability of remedy, lakes have ability of recovering from pollution. If the incoming amount of pollutants is small and is less than the recovering ability of the lakes, then there exist steady state: all the pollutants are consumed to make the incoming amount and the outgoing amount equal. The incoming amount of pollutants can be increased for various reasons. If the drain of a factory is carelessly discharged, the amount of a waste can easily surpass the recovering ability because the ability of recovering for artificial things is usually little. However, it is also possible that people in their daily lives drain foreign materials to the lake. There is not a big difference between industry and citizen in this sense.

There is still another problem to be considered. That is the density of pollution. Japan is a very small country. Yet the land holds 110 milion people. In addition, about 70% of the land is not suitable for housing. Inevitable therefore is the high density of population in the plain area. To hold the living standard, the density of our industry must be high as well. We believe this is the characteristic of our country and is the origin of the severe pollution problem. General public must admit that they are polluting the earth by living.

In countries such as Japan which hold only a small land, it seems that people must control their desire to some extent. They cannot hope ever-lasting development. There must be a compromise between the desire of inhabitants to raise their standards of living and the limitation arising from pollution. We may pick a few examples of this sort. The use of chlorine as a germicide in city water has been mentioned in this paper. But the usage of chlorine does not mean that the water in reservoirs can be polluted to high degrees. If the water in reservoirs is polluted with organic materials, addition of chlorine would cause the formation of chlorinated hydrocarbons which are harmful for the health of human being. Synthetic detergent is a target of attack by the public movement and soap which is made from natural oil is said to be nonpolluting. But it is not true, as everybody can recognize. To get the washing results obtained with the use of synthetic detergent, a large amount of soap will be needed relative to the synthetic. This use of quantity of soap will cause another pollution in addition to contribution to the shortage of oils and fats. Synthetic detergent was also blamed of containing phosphorus which will cause eutrophication of lake water. But people ignored that phosphorus was added to obtain the results of clean washings. If they are willing to rinse a few times more than that needed for the phosphorus-containing detergent, then we could remove all the phosphorus which is added to the detergent.

The above discussion tells us that the environmental issues must be considered from various aspects. In this connection we wish to point out an interesting story. Tetraethyllead is a well known antiknocking agent but is strongly poisonous also in addition to the fact that burning gasoline containing the lead compound means spraying lead in the environment. Various ways of avoiding the use of tetraethyllead yet maintaining high octane values of gasoline had to be sought. As a result, aromatic hydrocarbons were found to give high octane values. Then gasoline containing high percentage of aromatics was used. The result was the increse in air pollution. The aromatics which are sprayed into the air without burning act as a photosensitizer. It may be almost impossible at present to assess the outcome in the future from all the possible aspects, but we are responsible to the next generation in considering as many aspects as possible.

On the stand point that by living we pollute the earth, we might become pessimistic and passive. But this attitude is not healthy. Just as organisms possess the ability of remedy as well as the fact that the earth has the ability of recovery, we can rely upon the capability of science and technology. When the mankind suffers from starvation, chemists produce fertilizers. When the shortage of power was felt in the days when the hydraulic generation of power was the main source, the technology of thermal generation of power has developed. Necessity is the mother of invention. Whenever it is needed, the scientific technology will play a role in solving the pollution problem.

The point here is the cost. We are told by civil engineers that the banks of rivers are usually constructed so that they can survive floods of ordinary level but it is not economical to construct banks which would survive a flood that might occur once in several hundred years. The same kind of story is told by architects. Buildings are safe in the case of big earth quakes which occur every 30 years but may not be so if an earth quake hits which has a magnitude occurring only once in several hundred years. Of course, the present-day technology can construct buildings which can survive that big earth quakes but those buildings are not economical and not practical.

A similar problem can happen also in the cases of pollution. The present technology can protect environment almost completely and in an emergency, new technics may be invented. The problem is that this kind of technology is expensive. As a result, consumers may have to pay 200 yens to purchase a product which was sold on 100 yens before. Therefore people must be prepared to pay more money if they wish to halt pollution of the environment unless they are ready to abandon their desire of growing in economy and in material civilization.

One of the important points to be considered in education is to teach students that wise disposal of wastes which takes place on individual basis greatly helps in reducing pollution of the environment. In Japan, cities now collect wastes which are divided into the perishable and the nonperishable. It is odd on the stand point of chemists but plastics is included in the nonperishable. It is probably because, if plastics is placed in a furnace with paper and wood, it melts and clogs to make the efficient burning difficult. Therefore plastics is used for reclamation with glass, metals, and others which do not burn.

However, burning or reclamation is the final method of discarding. Those materials may be reused. Paper, metals, and glass can be recycled. Plastics may be thermolyzed to reproduce the original monomers which can be used again. This kind of recycle is not only good for the effective use of natural resources but also is useful for protecting the earth from pollution by excessive energy, because production of raw materials needs energy. One may discuss in class rooms how much energy is needed to make aluminum which is necessary for making a can.

In discussing these points, we are hopeful that people of the next generation will think of materials, for example those for wrapping, for which a mixture of paper, wood, plastics, and synthetic fiber is usually used. This kind of materials is not good for disposing because general public does not know how they can classify the materials. Industry should use materials which can be easily classified so that general public can discard them separately. This will help to avoid polluting the environment.

The environmental problems have various aspects and have no correct answer. The correct answer can be different according to the stand point of people. But we think it is worthwhile to discuss the problem in class rooms. That will help to understand that there are various people whose ways of thinking are diverse. The problems exist in teachers. Once we asked professors to use materials which are described in this text together with some others in class rooms. They refused to do so, however, simply because they did not know the correct answer: they cannot teach without knowing correct answers. We believe, however, that this is the essential point. Teaching is not always necessary. To aid thinking of students is more important in education. In that way, healthy attitude to thinking and living may be fostered. Why are we not prepared to tackle the problem which has no correct answer with students? This is really the way that scientists carry out their research and should not be "impossible" for university professors.

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Chemical Knowledge and View for Natural Substances and Industrial Products.

—— Approach from Familiar Materials of Everyday Life ——

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It is essential that the education of chemistry for non-major students should be based on a different principle from that subjected to major students. The orthodox and systematic method in teaching, if applied to non-major students, seems to be not only inadequate but rather baneful in view of the actual fact that it has brought about a trend for them to keep off or even to hate the chemistry.

Nevertheless, it is beyond question that importance and necessity of chemical knowledge and view has become increasing and enhancing in modern citizen life. From my own experiences of the teaching in our university and the editions of two enlightening books of chemistry, I wish to propose one principle for third education as follows.

An approach in the begining of the lecture to the non-major students must be done by indicating them the materials or facts which are so familiar in the citizen life that their attentions are drawn with the sense of questions. For example, a current social problem concerning chemical products, a medicine widely used to popular diseases, an interesting natural phenomena directly caused by chemical substances, a petroleum product in daily life and so on will be good targets to this approach. What should be emphasized is in neither individual nor systematic chemical knowledges, but wisdoms to understand a property of the material in the sense of chemistry. In this way, the teacher can inspire the students with interests to know how and why the compound changes to exert some influences to human life, how important a concept about an amount of the molecule in question is for discussion of biological effects and how closely the chemical phenomenon is related to the biological activity. Car drivers can, of course, manipulate the changing gear and the accelerator without difficulty, although they do not know necessarily the engine mechanics. Similarly teachings in detail of chemical structure and reaction mechanism are not rather needed for third education. The problem is what and how to teach for the chemistry served to the usual life.

In this line, trials in practice and its responses to students will be mentioned with some examples for further discussions.

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Chemical Knowledge and View for Natural Substances and Industrial Products.

Approach from Familiar Materials of Everyday Life

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An importance of the teaching chemistry for non-science students in school or the enlightenment of chemistry for citizen is now enhancing very much. Such task could be not only worthy of great efforts but also obligatory as chemists. Although the chemistry is a science which is the most closely concerned to materials in daily life, and knowledge and view of the chemistry are imperative as far as the mankind continues to live on earth, importance and necessity of the chemistry has not been recognized entirely in citizens. Nevertheless, recent trend for non-science students to keep off or even to hate the chemistry, is rather increasing in Japan. There are considered many reasons for such tendency. One must face to an environmental problem which is often believed to be due to a sin made by the chemistry itself. This is certainly a problem related to an interface between chemistry, economy and politics or journalism. However, when we probe deeply in it, the most important point if not all seems to lie in an education of chemistry in school for non-science and even major course students.

It is essential that the education of chemistry for non-major students should be based on a different principle from that subjected to major students. The orthodox and systematic method in teaching, if applied to non-science students, seems to be not only inadequate but rather baneful. One possible answer to solve the problem is an approach in teaching from materials, facts or events which are encountered in daily life of citizens so that attentions are drawn with the sense of familiarity and also question.

In this case, a systematic arrangement or historical development of chemical concept may not be followed necessarily, while such approach will give a benefit to students in view of a real possession of the chemical knowledge and view.

Let me show several examples as an interdisiplinary program particularly relating to biology or medicine besides chemistry. (Item 13)

1. History of Medicine and Development of Antibiotics. Starting from oriental drugs of natural sources, a history of chemistry of natural products is introduced where isolation and purification procedures of the active principle could be better explained. A story of the finding of the chemotherapy drugs such as salvalsan, or sulfonamide may arouse the student's interest very much especially for structural feature of the biologically active compounds. Discovery of penicillin by Dr. A. Fleming and efforts of chemists to develop it to the miraculous drug could be received to the students with feeling of admiration. It should be touched to the fact that successive endevors of chemists is now still continuing to modify penicillin or cephalosporin chemically in order to overcome a battle of human being against drug-resistant species of the microorganism. We

must not forget to emphasize the fact that exhibition of either a desirable curative effect or a undesirable toxic influence is a matter of balance depending on a dose of the medicine used.

2. Contribution of Chemistry to Practical Use of Vitamin and Hormone. In explanation of the action mechanism of vitamin B_1 and B_2, a passway of metabolism of starch through glucose and TCA cycle to afford amino acids and fatty acids, both of which are very important composite units to build up essential substances such as proteins or fats in living bodies can be substantiated. In this connection, an acquirement of energy in cell, roles of ATP or nicotin amide can be also mentioned. Teaching of the chemical concepts of oxidation and reduction will be an important key subject in this course.
Recent progress in hormone chemistry could be also imperative material in order to acquaint the students with contributions of the chemistry to human life. The teacher can select proper subjects in many studies of hormones such as oxytosin, insulin, cortisons, estradiol or even LH-RH where outlines of peptide or steroid chemistry will be elucidated. Concerning with the action mechanism, a homeostasis in human body must be also touched warning a danger of excess use of hormone drug like the pill.

3. Amino Acids and Nutrition. In Japan where 70% of food stuff of grains except rice is now imported, a nutrition problem may possibly happen some day in future, although people can not feel, for example, Kwashiorkor in Africa as an actual occurrence at

the present time. It is known that lysine, one of the essential amino acids, is insufficient in a diet mainly composed of grain. It was actually a serious problem in a couple of decade ago in Japan. About ten years ago, two Japanese chemical companies produced lysine by fermentation method to add this amino acid in bread of the school feeding to maintain a good balance of nutrition of children. However, the attempt was encountered with strong protest from citizens, although the government supported the companies, and finally it was frustrated. The reason is that the lysine as the industrial product contains 3,4-benzpyren, a well-known carcinogenic. A question is in a content of 3,4-benzpyren in problem. The authorized institution reported that the content is 0.06-0.30 ppb in the lysine. A simple mathematics is only necessary to figure out the real situation.

In one piece of bread made from 75 g of wheat flour, corresponding to one day diet, 75×10^{-13}g of 3,4-benzpyren was contained, whereas 75×10^{-7}g of the same compound is found in the same weight of smoking beef which people are often taking without any cares. Why such ridiculous ignorance happened, seems to be one of the problems relating to the chemical education for non-science students. Concept on an anount of the chemical substance, particularly when it is concerned with biological activity, must be emphasized in teaching.

4. Puffer Fish and Minamata Disease in Relation of Poison. While American people are only curious about a poison of puffer fish

just like towards California newt or South American colored frog, Japanese has custom to enjoy a taste of meat of puffer fish, and puffer poisoning is still occurring in more than one hundred cases a year. In 1964, two Japanese research groups as well as American group elucidated the structure of tetrodotoxin, a principle of this fish poison. Total synthesis of tetrodotoxin, was successfully performed by Prof. Y. Kishi in 1972. Such achievements of chemical researches should be informed to people to propagate the activities of chemists in social life. These fruits in chemistry may accelerate an investigation of neurology which will serve to heal the diseases in future.

On the other hand, Minamata disease is a painful warning to chemical industries. In this connection, meaning of catalyst in chemical process, conversion of metal to organometallic compound, solubility of chemical substances, lipophilicity and hydrophilicity, as well as metabolism of the chemical compounds in living body, must be lectured.

5. Morphine and Enkephalin as Analgesics. Another recent topics in bioorganic chemistry is in a finding of enkephalin. Release of the pain in human being is one of the biggest purposes of medical science to which chemistry can contribute at the fundamental stage. Morphine, an opium alkaloid, was found in as early as 1805 by F. N. Sertürner, the old chemist. But an angel sometimes changes to a devil. Attention should be paid to warn the terrible result of addiction by heroin, diacetyl morphine, informing the students how significant change in biological effect occurs just

by small modification in the molecule of organic compound. Endogeneous morphine, namely, endorphine that has alternate name enkephaline was found from the rational idea that an endogeneous active substance having an affinity to the receptor for exogeneous morphine should exist in living cell. Astonishing fact is a dramatic resemblance of chemical structures of morphine and enkephaline. This could become one gate for non-science students to enter a field of the chemistry with their familiar feeling.

6. Chemistry of Vitamin A and Its Role in Vision. Retinal is a splendid subject matter to inform students how collaboration of chemistry and biology clarified a mystery in the mechanism of vision. Students could understand well the necessity of vitamin A when they know a structural relationship between retinal and vitamin A. In this theme, they can also learn the concepts of cis-trans isomerism, conjugate double bond system, photoreaction and so on. If they are more acceptable, the teacher can go on the organic chemistry of terpenes, which are closely concerned to daily life, for example, as vegetable pigments, flower's scent, cosmetics etc. How the change of shape of the organic molecule is responsible for exhibition of the biological phenomenon could be a surprise for students to learn.

7. Bombykol and Heromone. Use of insecticides in Japanese farms is still a big problem in view of not only the national ecomony but also the environmental destruction. Change of the kinds

of insecticides actually employed should be informed in relation to the toxicity. On the other hand, many bacteriocides has been found in laboratories, which are now widely used to protect against the plant diseases. For instance, antifungal substance called blasticidin S found by Prof. H. Yonehara, was replaced with mercury-containing drug for protection against Imochi disease in rice field.

A rearing of silkworm had been an important work in Japanese farmer's houses before war age to support their economy. In 1956, Prof. A. Butenandt isolated a bombykol, the first heromone, from Japanese silkworm. Its attractive power is so strong that only 10^{-18}g per ml of bombykol is enough susceptable to male silkworm. This amount corresponds to 25 molecules of bombykol. In this calculation, the students have to recognize the reality of the molecule, and learn also a concept of the molecular weight as well as Avogadro's number. Geometrical isomerism could be an addition in this lecture. We should add further finding of hermone like gyptol for gypsy moth. A hope that some of them are promising agents to kill insects selectively without use of insecticide will be impressive knowledge by realizing the interrelation between daily life and progress of science.

I mentioned only several examples relating to interdisciplinary approach paticularly involving chemistry and biology. In a similar way one can pick up more and better programs even from the interface between physics, geology, mathematics and chemistry. What I should like to emphasize again according to my opinion, is that we should neither necessarily cover all fields of the chemistry based on systematic arrangement which is requested to science-major students, nor interpret exact chemical formula and structures. We should mention a minimum range of complicated reaction formula or complex structures, otherwise students may only react to reject them. Important thing for students is how to catch up chemical concepts or views which will serve for them to understand matters or phenomena in everyday life.

Concerning with Item 14, it is too hard for me to express a unique opinion about science-ecomonics-political interface especially on international dependence at the present time, so that I only give some programs which are related to the chemical products from industrial source.

1. Chemical Fertilizer and Professor's Anxiety. After war age, Japan fell into a crisis of food deficiency. All farmers had used tremendous amounts of ammonium sulfate as the only fertilizer to increase the harvests. Prof. R. Tsuchida pointed out that after ulilization of nitrogen from the fertilizer to plants, sulfate ion remains much in the rice field, and lime added in the field for neutralization of sulfate may result in desolation of all farm-land in Japan. His indication induced the government decision to change the main fertilizer from ammonium sulfate to urea which is now produced in large scale in many industrial companies.

   Such minimum knowledge of the chemistry is requisite to citizens and politicians rather than sophisticated chemistry. General properties of common elements or inorganic compounds must be taught in connection with the real problems.

2. Kanemi Affair and PCB. R. Carson's book "Silent Spring" has been read by many people in Japan. An unhappy affairs happened in Japan about ten years ago. In the oil factory refining food oil, PCB used as heat-insulation agent in distilling tower poured out from the broken wall and mixed with food oil. This disaster let people know a hazardous property of PBC for the first time. Taking this opportunity, the production of PBC stopped in Japan. However few people except for chemists can understand why PBC is so toxic, and how it is related to DDT. Here is also a subject matter for chemistry teacher to have to introduce in his course of the tertiary education. He must go back to periodical table of chemical elements to explain an abundance of elements in living body and also biochemical evolution related to the enzyme.

3. Fossil Fuel and Fate of Japan. No need for enumeration of the list of petroleum products in our present life. However, unexpectedly, people do not know how widely petroleum is used in so many materials of our daily use. After listing up industrial products originated from petroleum the teacher should elucidate some of the processes of chemical productions.
For students of economics and polytics, this could be a good target to introduce modern chemistry and relationship between

chemistry and citizen life because they, of course, recognize the situation that almost all sources of fossil fuel depend on supply from abroad and how decisively it is influenced to nation's fate. It should not be limited to situation of fossil fuels but extended to another natural sources like food-stuff or even energy supply, since Japan is now in more severe international circumstances perhaps than United State.

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Case Study – Colloids and Environment

Abstract

Ayao Kitahara

1. Colloidal Substances in Environment

We have a variety of colloidal substances in environment: smog, foamed river, emulsified oily substances in waste water and waste water polluted by fine solid particles. Those colloids are undesirable for mankind, but very stable. Destruction of them is an important study in environmental science and technology. I call tentatively the colloids environmental colloids. However, we have a variety of relatives of environmental colloids which are useful for mankind: insecticide spray, fire-fighting foam, emulsified agricultural chemicals, paints and inks. They are often unstable and the stabilization of them is an important problem in colloid chemistry and engineering. I call tentatively the collodis effective colloids.

Both colloids are quite the same from the view point of colloid chemistry. We can classify them into aerosols, foams, emulsions and suspensions. They are together called dispersed or particle colloids.

2. Characteristics of Dispersed Colloids

Dispersed colloids are composed of media and dispersed fine particles which are tiny phases and have definite interface.

Hence the formation of the colloids increases interfacial free energy and the colloids are thermodynamically unstable. However, interfacial electric charges and/or adsorbed polymer substances can make the unstable colloids metastable.

3. Equilibrium and Rate Process

The energetic behavior of dispersed colloids can be described in Figure 1. A is thermodynamically stable and flocculated state. B is unstable (metastable) and dispersed state. If V_{max} is higher, B is metastable — environmental colloids. If V_{max} is lower, B is unstable — often effective colloids. The stabilization of effective colloids and the destabilization of metastable colloids are rather the problem of rate process instead of that of equilibrium. Here the concept of rate is more important than that of equilibrium.

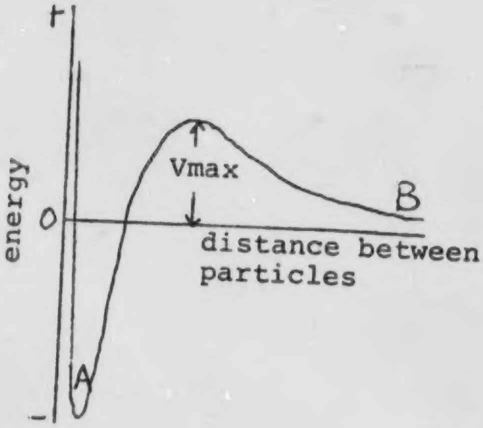

Figure 1.

4. Methods of Destabilization of Environmental Colloids

Now we have various methods of destruction of environmental colloids. Cottrel for aerosol, antifoaming agents or operations, demulsificating agents and operations and flocculating agents. They were born and suggested from studies on a fundamental problem of colloid chemistry: why and how have colloids been stabilized?

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A CASE STUDY--- COLLOIDS AND ENVIRONMENT

by AYAO KITAHARA

SCIENCE UNIVERSITY OF TOKYO

I would like to talk about colloids and environment as a case study. Why did I pick up this title in this seminar? A reason comes out from facts that colloids are familiar to our life and give us a few instruction in consideration of environmental problems.

I wonder people to whom I talk, that is, citizens or non-science students in universities or colleges have not learned about colloids. In the present textbooks of high schools in Japan, a few pages are only devoted to the description of colloids. The subtitle of"Colloidal solution" is included in the section of " Solution". We can see items of preparation of colloid, Brownian motion, Tyndall phenomenon, electrophoresis, coagulation of colloids and so on in Chemistry I(lower grade). But the system and the content of textbooks shall widely change in high schools in Japan from next year.

However, colloids can be seen and heard in our dairy life. Then I guess that non-scientists can understand the content of this talk, if I would talk about colloids qualitatively and understandably as possible as I can. I will try to do so.

Colloid chemistry has a wide region of contacting our life in chemistry. So to speak, it is a living and dairy chemistry. We can find many colloids in our dairy life. For instance, milk, butter, bread, coffee for breakfast; teethpaste, hand or face cream, shaving foam or cream and soap in morning toilet; dirty air , dust,polluted river in outdoor; paint, printing or writing ink and developer of copying mashine in office.

Most of colloids are not pure substances and seem to be complex systems. However, they can be cassified into a few classes and follow some laws and rules. Science of colloids contains physical view as well as chemical view. Colloids have, however, mainly been studied by chemists instead of physists, though they owe some theoretical parts to theoretical physists, for instance, Brownian motion to Einstein. Hence science of colloid has been called colloid chemistry. Recently it is often called colloid science. Then colloid science seems to be suitable as a topics for chemistry education.

I would like to present how colloid chemistry is related to mankind life and what colloid chemistry can teach to citizens or non-chemistry students through a case study-environment and colloids. I assume audiences or readers have graduated a high school or are studying in non-chemistry courses in universities or colleges.

1. COLLOIDAL SUBSTANCES IN ENVIRONMENT

Colloid is composed of coloidal particles and medium. The size of colloidal particles is approximately in the range of about 1 μm to 1 nm. But the boundary is vague. The state of medium is either of gas, liquid and solid. The state of particles is not fixed in the colloids of polymer molecules(molelcular colloid) and the solution of surfactants(micellar colloid), but it is classified into gas, liquid and solid in dispersed colloid or particle colloid. We take the dispersed colloid as colloid in this presentation, because we have many dispersed colloids in environment.

Here I cassify colloids in environment by the classification used in colloid chemistry in Table 1. Afterwards I call colloids in environment ENVIRONMENTAL COLLOIDS.

Table 1 CLASSIFICATION OF ENVIRONMENTAL COLLOIDS

Medium	Particles	Examples	Name
Gas	Liquid	fog } smog	Aerosol
Gas	Solid	smoke, dust } smog	
Liquid	Gas	foaming river	Foam
Liquid	Liquid	waste oil emulsion in river or from tanker	Emulsion
Liquid	Solid	dirty waste water, turbid river	Suspension
Solid	Gas	waste plastic foam	Solid colloid
Solid	Solid	waste colored plastics	

We have a variety of environmental colloids as seen in Table 1. But they are colloid-chemically cassified into aerosol, emulsion, suspension and solid colloid. The classification is very important, because we can estimate methods for stabilization and destabilization from each classificated kind of colloids.

We have other kinds of colloids which are man-made and useful for mankind. I call these colloids useful colloids. I listed up examples of useful colloids in Table 2.

Table 2 CLASSIFICATION OF USEFUL COLLOIDS

Aerosol	insecticide spray, cosmetic spray, other sprays
Foam	fire-fighting foam, shaving foam
Emulsion	emulsified agricultural chemicals, cosmetic cream, butter, mayonnaise
Suspension	paint, printing and writing inks
Solid colloid	plastic foam, synthetic leather, cookie

2. CHARACTERISTIC OF DISPERSED COLLOIDS

Environmental colloids and useful colloids shown in Tables 1 and 2 belongs to dispersed colloids. Here I have to illustrate about dispersed colloids.

Dispersed colloids have clear interface between particle and medium. Interface has interfacial tension as well as surface tension in surface. Interface is essentially same to surface, and it has wide definition including surface in it. Here I illustrate surface tension instead of interfacial tension.

Surface tension is thermodynamically specific surface free energy($\bar{G}_s$). How can this expression be elucidated? It is necessary for surrounding to do work to surface in order to make or enlarge unit surface, because molecules on surface is attracted to the interior of the liquid as illustrated in Fig. 1.

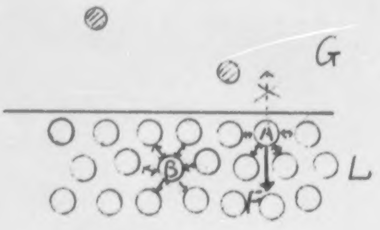


Fig. 1

Work done by surrounding is stored as free energy on surface. This unit(specific) surface free energy is really surface tension.

On the other hand, specific surface area of particles increases with decrease of the radius. We can calculate specific surface area(S_o) for spherical monodisperse particles(radius:a) as follows:

$$S_o = \frac{4\ a^2}{4/3\ a^3 d} = \frac{3}{ad} \qquad [1]$$

where d is density of particles.

If we take unit mass(1 g) of the particles, total surface free energy(G_s) is equal to

$$G_s = \bar{G}_s S_o = \frac{3\bar{G}_s}{ad} \qquad [2]$$

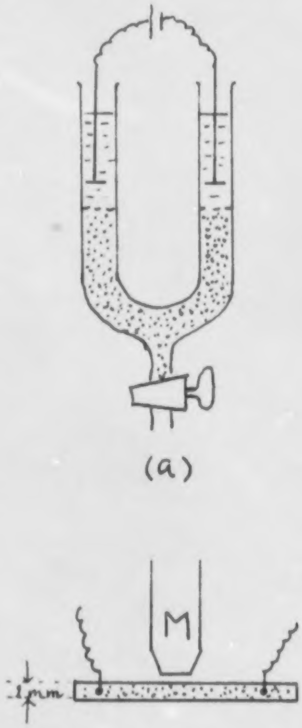
Then total surface free energy increases with decrease of the size of particles. Hence dispersed colloids are intrinsically or thermodynamically unstable because of increased free energy.

However, environmental colloids are very stable and embarassing mankind. Destabilization or flocculation of them is an important study for us. Why are environmental colloids stable and difficult to be destabilized?

Let us study on the stability of environmental colloids with use of a model colloid. we have silver iodide (AgI) colloids as a model colloid. AgI colloid is easy to be prepared and control the properties. Further we can find many scientific studies on AgI colloid in references.

Two examples of preparation of AgI colloids is described as follows:(a) 100 ml of $AgNO_3$ aq. solution(0.001 M) is added into 100 ml of KI aq. solution(0.002 M) with stirring. (b) 100 ml of $AgNO_3$ aq. solution(0.001 M) is added into 100 ml of KI aq. solution(0.001 M). For comparison, both of $AgNO_3$ and KI aq. solution(each 0.1 M) are mixed. Three mixture are shown in the slide. We can see that (b) is more turbid than (a), being both colloidal, though the last is clearly precipitate. It is better to be kept about 2 overnight at 80°C for electrophoresis.

We can measure electrophoresis on two samples of AgI colloids prepared above in U-shape cell or rectangular cell (Figure 2). The boundary between colloid and medium is directly observed after application of direct currennt voltage in the former. The movement of the particle is observed under microscope in the latter. It is better to use microscope in dark place to observe very tiny particles. Applied voltage is about 3-8 volt/cm.



(a)

(b)

Fig. 2

We can observe different velocity of the boundary or the particle between two samples of AgI colloids. (a) must show faster velocity going to the positive electrode than (b). That is, The sample (a) has more negative charges than (b). This is very simple experiment , but very instructive.

Turbidity is an indicator of the size of particles involved. More turbid sample(b) has particles of larger size than (a). It is tedious and high in grade to determine quantitatively the size of particle from turbidity. This is one of important parts of colloid chemistry. Now we use turbidity qualitatively. Then it is easily estimated that the sample (a) is more stable, difficult to flocculate and smaller in size than (b) because of more particle charges shown by electrophoresis experiment. This estimation is consistent with the fact seen in the preceding slide that (b) is more turbid than (a).

Here we have one important conclusion: Flocculation is disturbed by the presence of surface charges.

I would like to present you an additional experiment showing the important role of surface charge in stabilization of colloid(by A. Watanabe and R. H. Ottewill). We can prepare positively charged AgI colloid by mixing of KI aq. solution and excess $AgNO_3$ aq. solution(for example, $1x10^{-3}M$ and $2x10^{-3}M$, respectively). Then we add anionic surfactant, for instance, sodium dodecyl sulfate($C_{12}H_{35}SO_4Na$) aq. solution into the colloid and observe change of surface charge by electrophoresis.

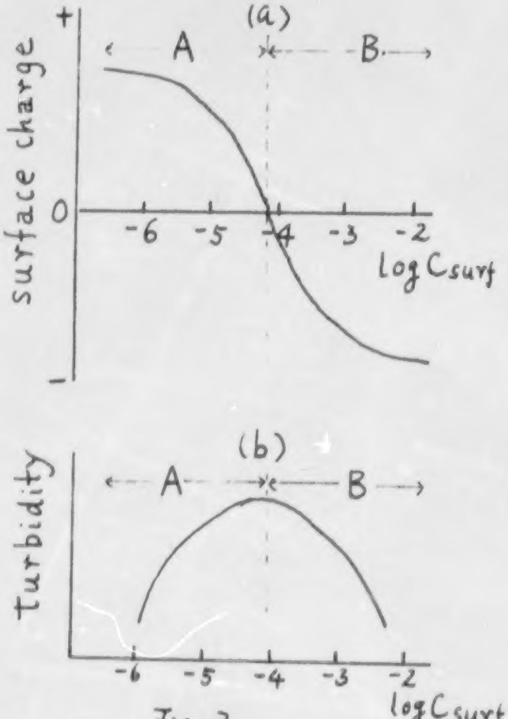


Fig. 3

We can see decrease of surface charge with increase of surfactant concentration as seen in Figure 3. Decreased charge goes through zero and take reversely negative charge. A profile of the turbidity indicating destabilization is shown in Figure 3b. It is seen from comparison of (a) and (b) in Figure 3 that decrease of charge corresponds well with destabilization, irrespective of the sign of charge. This example illustarates behabior of adsorption of surfactant as well as charge effect of colloid stabilization.

We notice here that surfactant plays both stabilizing and destabilizing roles in colloid stability. The surfactant is a stabilizer in region A and a flocculant in region B in Figure 3.

I would like to go to another talk on colloid stability. I use other model colloid: Synthetic latex of polystylene. This latex can be easily synthethized. But the synthesis is not presented , because it is in detail for citizens or non-chemists. The particles of the latex obtained are spherical and monodisperse.

The effect of polymer on stability of the latex containing $BaCl_2$(0.0125 M) was examined(by S.G.Ash and E.J.Clayfield). Polyethylene oxide, PEO(molecular weight 9×10^6) was used as polymer.The change of turbidity(accurately, rate of turbidity) with the concentration of PEO was measured. The result of Figure 4 was obtained.

We can see in Figure 4 that small quantity of PEO destabilize the colloid, but large quantity stabilizes it. The mechanism can be illustrated from interaction of adsorbed layer formed by polymer as shown in the OHP.

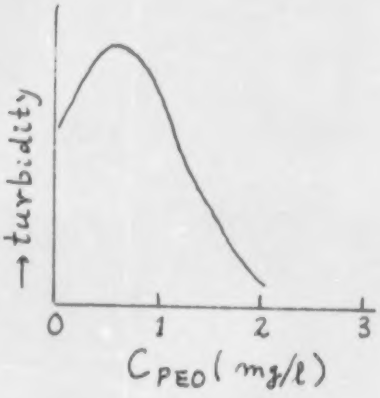


Fig. 4

It is seen here that polymer plays both stabilizer and flocculant similar to surfactant.

We can deduce some consideration for stabilization of colloids from the preceding experiments with use of the model colloids.

COLLOIDS CAN BE STABILIZED BY THE PRESENCE OF SURFSCE CHARGE AND/OR ADSORBED LAYER OF POLYMERS.

Furthermore, the effect of surfactant influencing surface charge and polymer making adsorbed layer is very instructive. They play flocculants(destabilizer) as well as stabilizers(dispersants). We have to know the concept of the optimum to use them. In science, "the more, the better" is a dangeous concept. This is an important instruction to us from colloid chemistry and an important concept in environmental problem.

3. EQUILIBRIUM AND RATE PROCESS IN COLLOIDS

In this section, with use of colloids I would like to talk the relation between equilibrium and rate process which are very important concept in chemistry. I will illustrate it as comprehensive as I can.

We learned electrical repulsion and repulsion between adsorbed layers. If we would have no other effects, particles should be stabilized by either of both effects. However, it is not true. Charged particles flocculate sometimes. Why?

Molecular attractive force, van der Waals force is described in high school text books in Japan. Because particles composed of molecules have a great many pairs interacting with molecular attractive force, particles must work attractive force on each other as summation of molecular attractive force. This expectation was realized by the calculation by Hamaker. His interesting result is that attractive force between particles is long-range force, though molecular force is very short range. This result is very important. Here and afterwards, instead of force, we use potential energy of force which can be obtained from integration of the force with distance. The approximated potential energy of the attractive force between particles is expressed as follows:

$$V = -\frac{Aa}{12h} \qquad [3]$$

where A is a constant. Other letters are illustrated in Figure 5.

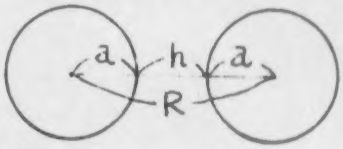


Fig. 5

Electric repulsion is complex in aqueous solutions, because oppositely charged ions to surface charge are clouded around particles and diminish the repulsion by the Ohmic law. We can easily know that potential energy of Ohmic repulsion between particles is proportional of 1/R(R is the distance between centers of two particles). Then the potential energy of electric repulsion diminished in aqueous solutions is probably steeper than the curve of 1/R.

According to the accurate theory(Derjaguin, Landau, Verwey and Overbeek), the potential energy curve A shown in Figure 6 is known to be proportional to e^{-kh}. We write it tentatively as follows:

$$V_R = K'e^{-kh} \qquad [4]$$

The proportional constant K' involves many factors, especially it must involve square of the quantity on surface charge(q), because the stability of the dispersion is relating to surface charge (irrespective of the sign) as seen in Figure 3. Hence we write V_R as follows:

$$V_R = Kq^2e^{-kh} \qquad [5]$$

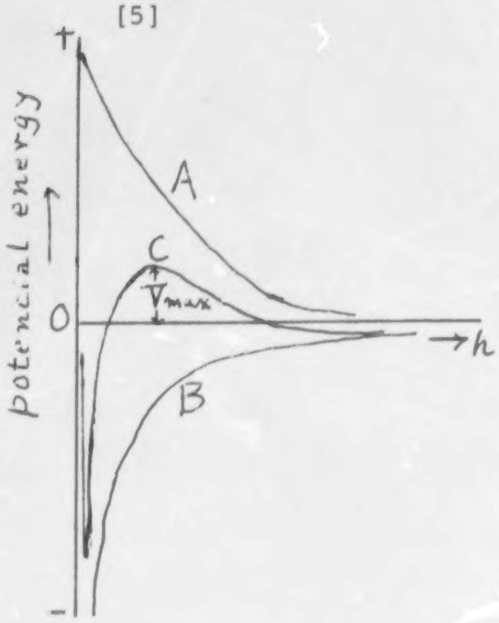


Fig. 6

where k is expressed by eq. 6.

$$k = K''Z\sqrt{C} \qquad [6]$$

where K", Z and C are the constant, the valency of ions and the concentration of the ions, respectively. The ions result from salt involved. Here we have the effect of salts added on the dispersability.

On the other hand, eq. 3 can be depicted like the curve B in Figure 6. V_R and V_A are scalar quantities and calculated algebraically. That is, total potential energy is obtaind as follows:

$$V = V_R + V_A \qquad [7]$$

which is depicted as the curve C in Figure 6.

The curve C in Figure 6 is similar to activation energy curve in reaction kinetics. Energy barrier present in Figure 6 (V_{max}) has the similar meaning to activation energy. Now we imagine that particle P_1 is approaching particle P_2 in Figure 7a. A is thermodynamically stable site in Figure7a similar to A' in Figure 7b and the two particles must flocculate at this site A. When V_{max} is higher, the rate of the flocculation is very slow by the presence of the high energy barrier, the behavior being similar to high activation energy in chemical reaction.

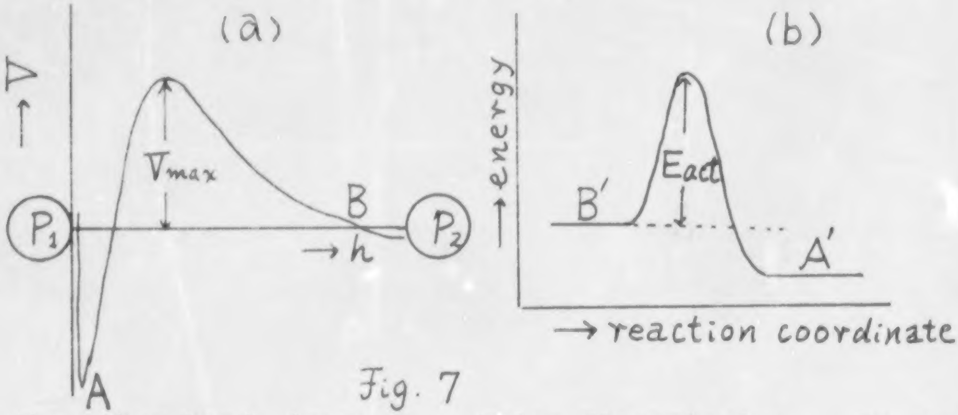


Fig. 7

On the other hand, lower V_{max} helps flocculation. To stabilize colloids electrically, higher V_{max} is necessary. Thus stable environmental colloids have higher V_{max}.

Every dispersed colloids have necessarily deep potential well(site A in Figure 7a) because of the presence of attraction shown by eq. 3. As the result they are thermodynamically unstable and have to flocculate. However, some colloids have higher surface charge and resulting higher V_{max}. Then the colloids are slow to flocculate and apparently stable (metastable). We can see their examples in environmental colloids.

Some useful colloids are not stable because of lower surface charge and therefore lower V_{max}. To make them stabilize, we have to elevate V_{max} by increase of surface charge.

An important factor to stabilize or destabilize dispersed colloids is rate process which depends on the height of V_{max} instead of equilibrium.

4. METHODS OF DESTABILIZATION OF ENVIRONMENTAL COLLOIDS

We can find methods and chemicals for destabilization or flocculation of environmental colloids from consideration and discussion given in the preceding sections.

A method suggested from eqs. 3-5 is the lowering of V_{max} by decrease of V_R. This can be done by (i)decrease of surface charge and (ii) increase of the concentration and the valency of ions involved. Decrease of surface charge can be done by addition of some surfactants oppositly charged as seen from Figure 3. However, we have to use optimum quantity of the surfactant as discussed before. Polyvalent inorganic salt ions as $Al_2(SO_4)_3$ decrease V_R by lowering of surface charge due to partial adsorption and increasing of k in eq. 6.

A small quantity of polymer of high molecular weight and high solubility added works as flocculant. The mechanism of the flocculation was illustrated in Section 2. Here we have to notice the quantity of the polymer. Excess polymer plays as dispersants. Polyvalent inorganic salt and polymer flocculant are often used together for the treatment of waste water.

We can use silicone, higher alcohol, fat and others as antifoamers or defoamers. They are adsorbed strongly or preferencially on interface, drive out stabilizer as surfactant, and destabilize the foams.

Acid is used as demulsifier for soap-stabilized emulsion. Some of defoamers can work as demulsifiers under similar effect.

However, we have to take care of secondary pollution by chemicals used for flocculation, defoaming or demulsification.

OPTIMUM IS NECESSARY AND IMPORTANT.

Physical operations to destabilize environmental colloids are hopeful, because they don't carry secondary pollution from chemicals. A few methods are suggested from the discussion given above.

Electropheresis is probably used to remove charged colloids in aqueous dispersions. Here electrodeposition occuring at electrodes helps to remove the charge of colloids.
The electrical methods has been used in air as Cotrell apparatus.
This is famous and often used in many industries, for instance, cement, ceramics, power station using coal and so on.
This includes colona discharge, charging of particles, electrophoresis and electrodeposition.

Flotation method utilizing different wettebility is also used to clarify waste water. Here hydrophobic particles adhere to bubbles produced and float up with bubbles. Bubbles are made by two methods: (i) Sending air in dispersions through filters or porous materials or (ii) sudden reduction of pressure(a few atomospheric pressure) applied before.

Finally I have to refer to removal of heavy metal ions in water purification. We have many methods to do so, for instance, ion exchange, pH change and so on. They can be also removed colloid-chemically. I refer to two novel methods.

One is an ion floatation method and the other a ferrite method. In the former, for instance, we use polycarbonic acid salt as sodium polyacrylate and a foaming agent. The polymer ion makes insoluble salt of a heavy metal and the salt floats up with bubbles. In the latter, some ferric soluble salt is added into water treated, followed by addition of ammonia. Heavy divalent metal ions react with them and change to ferrite-type compounds, which are removed magnetically. The plant of this method has been made (by T. Takada).

Abstract

What should we teach ? Kazuo Saito

The Elements — The most fundamental concept of chemistry

1. Historical development of the understanding of chemistry.
2. The elements and the civilization.
3. Discovery and classification of the elements.
4. The elements in nature.
5. What does govern the characteristics of the elements ?

Chemistry has developed itself into modern science by introducing an appropriate idea that all the variety of materials are formed by rather limited variety of the elements. The idea of "element" was discussed by philosofers and metaphysicists in Greece, China, Persia and India since before the birth of Christ. However, elements in modern context have been discussed only since the beggining of 17th Century. It seems essential to let young students understand how the idea of elements was established on the basis of experiments. It is also important to tell them how individual elements were discovered in nature.

The development of human civilization is closely connected to the use of new variety of materials, particularly metals. It is worthwhile to let them understand how the use of a new metal contributed to the progress of human life and culture, and why such a progress was brought about. Recent development of civilization is certainly the result of modern achievement of science and industry, which bases on the fundamental idea — the chemical elements. We have to tell them how hopefully we can expect further development of human welfare by exploiting new frontiers of material science.

The idea of the elements is abstract. It is different from "atoms" and also from "simple substance". These ideas are sometimes mixed up. It seems the study of occurrence and circulation of the elements in nature provides fruitful results. Students may find interest that all the chloride ions in nature have originated from the oceanic salt. The origin of organism on the earth can be also a good target of discussion. We can show how the primitive organisms in ancient ocean made use of traces of transition elements, which were in very diluted state, but, nevertheless, had indispensable function as components of essential compounds in living bodies, e.g. enzymes.

Further sofisticated understanding of the elements can be expected by discussing the structure of atoms, and energy levels of the electrons. However, we have to teach chemistry to those who are not specialized in chemistry without the use of chemical formulae. "Ordinary method of expression" is inadequate. We should not sacrifice the exactness of our story, but we have to find a way to make chemistry more easily digested without telling a lie. This must be an important challenge for teachers in chemistry.

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What should we teach ?

The Elements —— The most fundamental concept of chemistry

By Kazuo SAITO (Chemistry Department, Faculty of Science,
Tohoku University, Sendai, 980, Japan)

Chemistry has developed itself into modern science by introducing an appropriate idea that all the variety of materials are formed by rather limited number of elements. It is the essential idea of modern chemistry that the elements are the basic substance which gives rise to the complicated physical world.

University students are intelligent. Regardless of the major project of their own studies, they have common enthusiasm for getting an overall view concerning the world — both physical and mental — through their studies. Simple accumulation of individual knowledge does not satisfy their curiosity. We have to endevor to convince them that chemistry is an important branch of natural science and hence of human knowledge, not only because it provides useful measure for improving the material comfort of mankind, but also because its development brings about affluent outcome to the mental world. Thus we have to convey them our achievement which is purely of intellectual nature. —— The logic of pure chemistry. The guiding principle of chemistry is analogy and induction. There ha~~s~~ve been cases in which intuition has played an important role in developing chemistry, but they are rather exceptional. It seems desirable and useful to let the students understand and enjoy the logic of induction through the study of chemistry.

1. Historical development of the idea of ~~chemistry~~ the elements

It is very interesting that ancient phil~~i~~osophers had a common idea that the material world was composed of a few "elements". Thales thought that water was the origin of everything in 6th Century B.C., whereas Anaximenes (6th B.C.) and Herakleitos (5th B.C.) reckoned air and fire, respectively, were the essential things which made everything under the heaven. Aristoteles's idea that water, earth, air and fire were the four elements of the universe gave remarkable influence to the philosophers and metaphysicists for a long time. Ancient India~~m~~n philosophy also reckoned these four elements as the fundamentals of the universe. On the other hand, ancient Chinese philosophers had different ideas. Taoism gave influence to Confucianism, but the fundamental idea was that positive and negative were the important fundamentals confronting each other. They thought that such a confrontation brings about five elements, which were wood, fire, earth, metal and water. A Confucianism philosopher in 10th Century A.D. gave an illustration which showed such a principle (Fig.2)

Fig 1

Table 1

Fig 2

Despite of detailed difference of the ideas, a common enthusiasm is seen that ~~the~~ all the complicated things in the universe were composed of rather small varieties of the "elements". Such a desire should be common to the human being, and lies underneath apparently different ideas expressed by the philosophers. The same desire also forms the basis of chemistry as modern science. There is, however, a great difference between such ancient "elements" and modern "elements". The former ~~be~~ is the product of personal meditation, but the latter bases on experimental facts of universal validity. Aristoteles stated that we had to start from known facts. However, he sometimes took something for granted without concrete basis. In this context he was not free enough from the current idea of the time.

Long period of medieval times brought about confusion. Alchemists left important heritage of experimental technique, but their leading idea was quite wrong. First, they thought that elements were interchangeable. Second, they did not want to make their individual achievements common assents of the human being. They are not to be blamed too much. Because there was no way in those days to satisfy their ambition unless they got wealth or praise from their patrons. The development of chemistry as modern science became appreicable since 17th Century A.D., and this period should not be independent of the general development of humanism. Intellectual achievement became to be appreicated in the human community and making one's achievement public was the way to satisfy his desire for fame.

Fig 3

Modern development of the idea of "elements" is now written in all the text books of chemistry for high schools, and there is no need to repeat here the contribution of pioneers of chemistry in 18th and 19th Century. Students majoring in humanities, social sciences etc. would find more interest in the trend of thought rather than in the detailed way through which the idea of "elements" was established.

Table 1 Four fundamentals in Buddish philisophy ("Shidai")

Names	(Sanskrit)	Shape	Symbol of	Color	Function
earth	prithivi	square	hardness	yellow	hold other things
water	ap	circle	humidity	white	adopt other things
fire	tejas	triangle	heat	red	mature other things
wind	bayu	half circle	movement	black	grow other things

2. The elements and civilization.

Civilization of the human being consists of various components. However, high grade civilization is always accompanied by high grade material civilization, which is closely related to the use of particular raw material. Thus human civilization in the past is classified on the basis of the main material upon which the civilization was established. Stone age civilization based on the use of silicates, natural and artificial, whilst bronze age and iron age did on the use of particular metals. The knowledge about the properties of metals seems to have been quite advanced in ancient days. Table 2 gives an example how ancient Chinese were aware of the characteristics of the mixture of copper and tin in 300 B.C., and used bronzes of different compositions for particular purposes.

Table 2

Iron is obtained with more difficulty than copper, and it is believed that the use of iron and steel became common much after the bronze age. However, it should be noted that the famous Greek poet Homeros wrote about forging of iron in 700 B.C. In China too, iron seems to have been known since Chou Dynasty.(10 to 3 Centruy B.C.)In north Korea a relic of arrowhead was found in a ruin which is believed to be of 200 B.C. Since iron is easily stained, its relics may have stained and does not remain in due form.

In modern industry the importance of iron and steel need not to be emphasized. Table 3 gives the development of iron industry in Japan since the beginning of 19th Century. Japan learned iron and steel from China presumably through Korea. The engineering technique was improved to produce

Table 3

Table 2. Usefulness of bronzes of different compositions.

Name of alloy	Ratio Cu/Sn	Use	Properties in modern context
Bells and tableware	6/1	bell, table set	high reflectivity, beautiful golden color
Ax	5/1	ax and battleax	high tensile strength
Spear	4/1	spears	high tensile strength and hard surface
Sword	3/1	sword	high tensile strength and hard surface
Arrow	5/2	arrowhead	high Brinell hardness
Mirror	1/1	mirror and condenser	almost white, high reflectivity

Table 3. Development of refining of iron and steel in Japan

Item	-1857	1858-1900	1901-1918	1919-1945	1946-
Factors determining terms of location	supply of the raw material			market	market
	iron sand and and charcoal	iron ore	coal		
Raw material	iron sand	iron ore	iron ore	iron ore	iron ore
Reducing agent and energy source	charcoal and firewood	charcoal and coke	coal and coke	coal, coke electricity	coal, coke, electricity, natural gas
Arrangement for pig iron	furnace with manual bellows	high furnace	high furnace	high furnace	large scale high furnace
Raw material for steel	iron sand	pig iron	pig iron, scrap iron	pig iron, scrap iron	pig iron, scrap iron
Arrangement for steel	furnace with manual bellow	open hearth	open hearth, converter, electric furnace	open hearth, converter, electric furnace	open hearth, converter, oxygen converter
Power source	manual	water wheel, steam engine	steam engine	electric motor, internal combusion engine	electric motor, internal combusion engine, nuclear power
Transportation	catle, boat	catle, horse tramway	railway, steam boat	railway, steam boat, motor car	railway, motor car, big steamship
Raw material imported from	inland	inland	inland (except coal)	inland and economic sphere of influence	almost all overseas

high quality swords containing molybdenum. However, the natural resources were limited, and mass production became common only at the end of 19th Century, by use of imported iron ore and coal. The increase in amount of production of iron and steel is illustrated in Fig. 4.

Fig 4

The use of aluminum also provides a good example of interesting application of characteristics of a particular element. Alum has been known long both in the East and the West. The word alum seems to have come from Latin"alumen", which means that the material gives luster on dying. Alchemists used alum extensively for many purposes. Chinese dyers also used alum since very old days. The reason why alum was so widely used may be that it gives a high charge colorless cation. Aluminum is certainly the unique element which is abundant in nature, and gives +3 colorless cations. (Rare earth elements also give similar ions, but they are certainly not common.) We find how our ancestors were wise to have made use of that aprticular element. A.S.Marggraf found in 1754 that an element was contained in alum. He obtained a very stable white solid (alumina in today's nomeclature), which was believed the "einfacher Körper" and included in Lavoisier's table of the elements as "corps simple". F.Wöhler was the first who obtained aluminum metal in 1827 by the reaction of alumina with potassium. S.H.Deville got aluminum metal by an electrolytic method from clay and exhibited the metal at International Exposition in Paris in 1855 in the name "l'argent de l'argile". Napolean III thought that the metal particularly suited for making the armor of cavalry and gave him research grant. In those days, however, there was no electric generator, and the electrolysis required a large pile of batteries. Mass production of aluminum had to wait for sometime until electricity became cheaply available. The element aluminum has many characteristics including its low density, and we can show how our modern civilization owes to this element.

Use of manure gives another good example of the relationship between the elements and the material civilization. Ancient farmers used excrements of cattle and men and vegitable manure heap. Then bone ashes and oil cake were added. We now find that those manures contain essential elements for plant growth in appropriate compositions. J.Liebig was the first who showed that for the growth of plants the elements and not compounds are essential. He showed that the elements changed their chemical forms to be easily absorbed by the plants, and inorganic manure was as useful as organic manure. He demonstrated that ammonium sulfate increased the yield of wheat and barley, and phosphates gave good influence on the crop of beet. However, the chemicals were too expensive for farmers, and they had to wait for the mass production of chemical industry. We can now show which kinds of elements are essential for plants. We can also tell that the element, not its particular compound, is needed by living bodies. Such stories will help the students to understand the meaning of "elements". Figure 5 shows the relationship between the crop of rice and the production of chemical fertilisers in Japan. It is seen that the increase owes mostly to the increase in nitrogen fertilisers.

Fig 5

3. Discovery and classification of the elements

The history of discovery of the elements provides a useful material for understanding the idea and the importance of the elements. Also non-major students may be interested how the variety of elements were classified and placed in order as e.g. periodic table. Before the understanding of the idea of the chemical elements the discovery depended mostly on luck of the discoverer. After Daltons's definition of the elements a lot of endeavor was devoted to discovering a "new" element. The significance of the discovery of the new element changed after Mendeleev's establishment of the Periodic Table. The discovery of germanium and particularly of the rare gas elements is a drama without scenario. The story may satisfy the curiocity of students even majoring in humanities and social science. However, I do not think I need to repeat the history of Lord Rayleigh and W.Ramsay.

This field of talk should be concluded by the preparation of new elements which are not occurring in nature. The story of the nuclear reaction seems slightly outside of chemistry in narrower sense. However, if time allows, the "discovery" of nuclear fission, and other nuclear reactions may be included in the syllabus. It is also important to let the students have appropriate understanding on radioactivity and radiation. Very often these two technical terms are mixed and can cause inappropriate movement concerning the future use of nuclear energy as common property of the human being.

Table 4

Table 4   History of discovery of the elements.

Period	Number of elements discovered	Names of the elements
Old	11	Au Ag Cu Hg C Sn Pb S Fe Bi Zn
17th	3	As Sb P
18th (-1750)	3	Co Ni Pt
after 1751	10	H N Mn O W Te Ti U Mo Cr
19th (-1850)	31	Pd Os Ce Rh Ir Na K Mg Ca Sr Ba B Cl I Li Cd Se Si Ta Br Be Al Zr Y La Th V Er Tb Nb Ru
after 1851	25	Rb Cs Tl In Ga Yb Sc Sm Ho Tu Gd Ge Pr Nd F Dy Ar Kr He Ne Xe Eu Po Ra Ac
20th	5	Rn Pa Lu Hf Re

(almost in the order of discovery; synthesized elements are not included)

4. Occurrence of the elements in nature.

Since the man kind exists on the earth which is a member of the solar system in the galaxy, the occurrence of the elements in nature is of a common interest of the human being.Presumably the first question of a boy or a girl could be whether the abundance of the elements be common in other stars. There are science fictions that gold is very abundant on a certain star and water is very precious. Hence the talk can start from the comparison of the abundance of the elements in various places. Table 5 gives the order of abundance of major elements in nature. The figures are converted into ratios of abundance of given elements to that of oxygen. The elements are drawn up in the order of abundance in the earth.

Table 5

One can easily see that some elements which are very abundant in the universe are missing on the earth. They are hydrogen, helium, carbon, nitrogen, neon and argon. We can show that those elements forming gaseous molecules by themselves or with very abundant elements are not retained on the earth, only because the gravity of the earth is not big enough to keep light gas molecules in the gravity sphere. We must then tell that the abundance of the elements in the universe is ruled by the properties of the atomic nucleus, i.e. by the rate of nuclear reactions at which heavier elements were "synthesized" from hydrogen. On the other hand, the distribution of the elements within the universe is controlled by the properties of the atom particularly of the electrons. This is one of the most important points

Table 5 Abundances of the elements in nature

Place	O	Si	Mg	Fe	Al	Ca	Ni	Na	S
galaxy*	1	0.047	0.042	0.028	0.0044	0.0023	0.0013	0.0020	0.0017
	3	7	8	9	12	13	15	14	10
earth total	1	0.375	0.351	0.257	0.029	0.021	0.018	0.013	——
	1	2	3	4	5	6	7	8	
earth surface**	1	0.52	0.039	0.095	0.15	0.068	0.0002	0.019	0.0012
	1	2	8	4	3	5	24	6	15

* from the Sue55)-Urey diagram ** from the Clarke number

of fundamental chemistry that how the properties o~~f~~r "personality" of an element depend on the nculeus or the electrons of the atom.

Circulation of the elements at the earth's surface provides an interesting material for ~~the~~ understanding ~~of~~ the importance of the elements. Figure ~~5~~ 6 exemplifies the circulation of carbon near the surface of the earth. Cabon atoms change their state to a marked extent (carbon dioxide, hydrocarbons, carbonate ions, complicated organic compounds, etc.) and move on the surface of the earth. It looks like the transmigration of the soul as taught by Buddism, and may be better expressed by "metempsychosis" ("rinne" in Japanese). Circulation of the chloride ion can also provide a good story, that almost all the chloride ion found in fresh water on the surface of the earth has come from the sea. All these stories will provide useful material for the understanding of the idea of "elements". Thus students can get enough fundamental knowledge to deal with da~~y~~ily matters like the pollution of air or water by heavy metals.

Fig 6

One very interesting topic concerning the natural occurrence of the elements would be the origin of life in early geological ~~days~~ age. Table 6 gives the approximate concentration of various elements in sea water, and it also shows how the living bodies require~~s~~ th~~o~~ese elements in the bodies. Most abundant elements of Group 1 are all indispensable for all varieties of organism. Only a few varieties of the elements of Group 2 are indispensable, whereas less abundant

Table 6

Table 6 Concentration of the elements in sea water and their indispensability for living bodies.

Group	Concentration	Elements
1	$> 10^{-3}$M	$\underline{\underline{\mathrm{H}}}, \underline{\underline{\mathrm{O}}} \gg \underline{\underline{\mathrm{Na}}}, \underline{\underline{\mathrm{Cl}}} \gg \underline{\underline{\mathrm{Mg}}} > \underline{\underline{\mathrm{S}}} \quad \underline{\underline{\mathrm{K}}}, \underline{\underline{\mathrm{Ca}}} >$ $\underline{\underline{\mathrm{C}}} > \underline{\underline{\mathrm{N}}}$
2	$10^{-7} - 10^{-3}$ M	$\underline{\mathrm{Br}} > \underline{\mathrm{B}} > \underline{\mathrm{Si}}, \mathrm{Sr}, \underline{\mathrm{F}} > \mathrm{Li} > \underline{\underline{\mathrm{P}}} >$ $\mathrm{Rb} > \underline{\mathrm{I}}, \mathrm{Ba}$
3	$10^{-9} - 10^{-7}$ M	$\underline{\underline{\mathrm{Mo}}}, \underline{\underline{\mathrm{Zn}}}, \mathrm{Al}, \underline{\mathrm{V}}, \underline{\underline{\mathrm{Fe}}} >$ $\underline{\mathrm{Ni}}, \mathrm{Ti}, \mathrm{U}, \underline{\underline{\mathrm{Cu}}}, \underline{\mathrm{Cr}} >$ $\underline{\underline{\mathrm{Mn}}}, \mathrm{Cs}, \underline{\mathrm{Se}}, \mathrm{Sb} > \mathrm{Cd}, \underline{\underline{\mathrm{Co}}}, \mathrm{W}$
4	10^{-9} M >	no indispensable element

= indispensable for all the varieties of living bodies

_ necessary for some varieties of living bodies elements of Group 3 are more widely needed by the organism. These elements are mostly transition elements, and their ionic charge is changeable. Hence they are more useful as electron transfer medium, and therefore as components of cofactor of metalloenzymes. Primitive organism in early geological age collected these metal ions from very diluted solution and gave them very important role in the metabilism. Most of these transition elements are in the first long period of the periodic table, whilst molybdenum is the uniuge element of the second long period which is indispensable for every organism. We can see how the evolution in early stage was governed by the composition of ancient ocean. Further less abundant elements including mercury and arsenic are poisonous presumably because the organism has not adapted itself to these elements throughout the history of biological evolution.

5. What does govern the characteristics of the elements ?

The following part may be included in the syllabus of the lecture only when the time allows and the students show symptoms to be interested in the lecture. The most important item which is taught in this context is the roles of atomic nucleus and the electrons. Almost all the phenomena related to the nature of the elements are governed by the electrons. However, the electronic state of the elements is largely controlled by the nucleus. The idea of electron cloud may be too sophisticated. Bohr's models seem to suffice. Details of the energy levels of the orbitals are not necessary, but the grouping of the orbitals, i.e. 1s, 2s, 2p etc. must be included. The idea of ionization energy seems quite suited for the understanding of affinity between the valence electrons and the core composed of atomic nucleus and inner electrons. Importance of the configuration of electrons may be demonstrated by the Zintle phase, in which e.g. uni-negative ion of gallium gives graphite structure. On the other hand the tyrranous behavior of the atomic nucleus can be easily exemplified by comparing the properties of metallic nickel, univalent cation of copper and bivalent cation of zinc.

One of the essetials which we have to deal with non-major students is to let them understand the importance of chemistry both in daily life and in mental world. This goal may be achieved in many ways, but one hopeful approach could be to relate the development of chemistry to the progress of civilization both in material and mental context. I have deliberately given examples related to the civilization in the East, because they are more familiar to Japanese students. I hope such an article may provide some material to improve mutual understanding between East and West.

Figure Captions

Fig. 1. Aristoteles's four elements and their mutual relation.

Fig. 2. Principle of positivity and negativity, and the five elements in Chinese metaphysics. ("Taikyoku-zusetstu")

Fig. 3. Signs of some elements in Greece (upper) and of of Alchemists in Medieval age(lower).

Fig. 4. Production of iron in Japan. (per year)

Fig. 5. The production of rice, the area of rice field and the production of nitrogen fertilisers in Japan during the period 1900 to 1975.

Fig. 6. Circulation of carbon at the earth's surface. (Figures are grams of carbon per square centimeter of the surface of the earth.)

FIG. 1

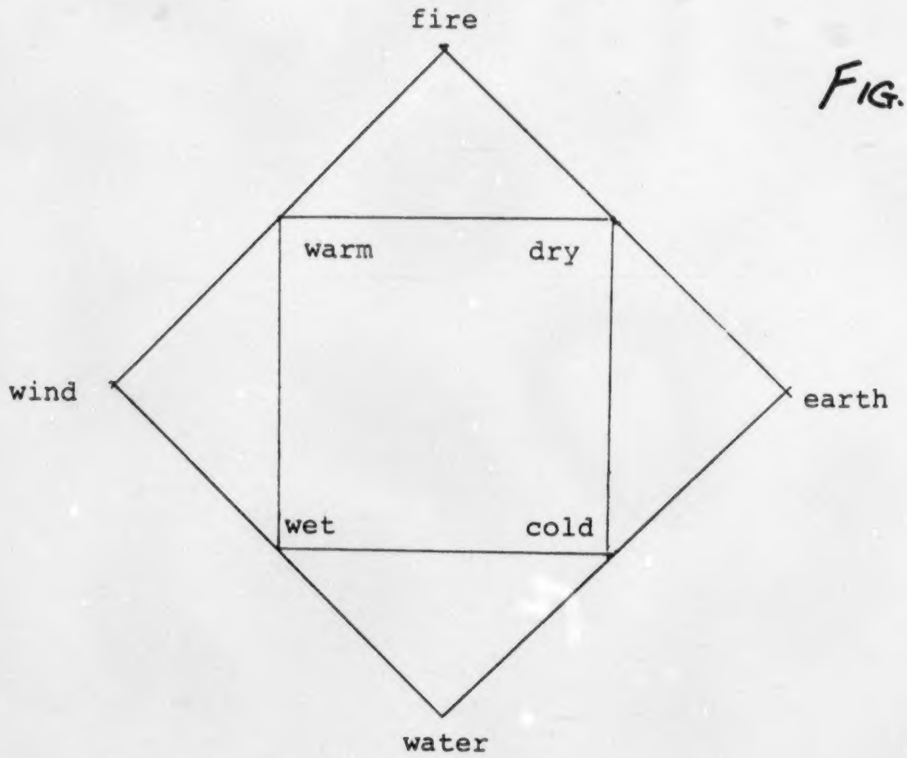

fire
warm
dry
wind
earth
wet
cold
water

Fig 2.

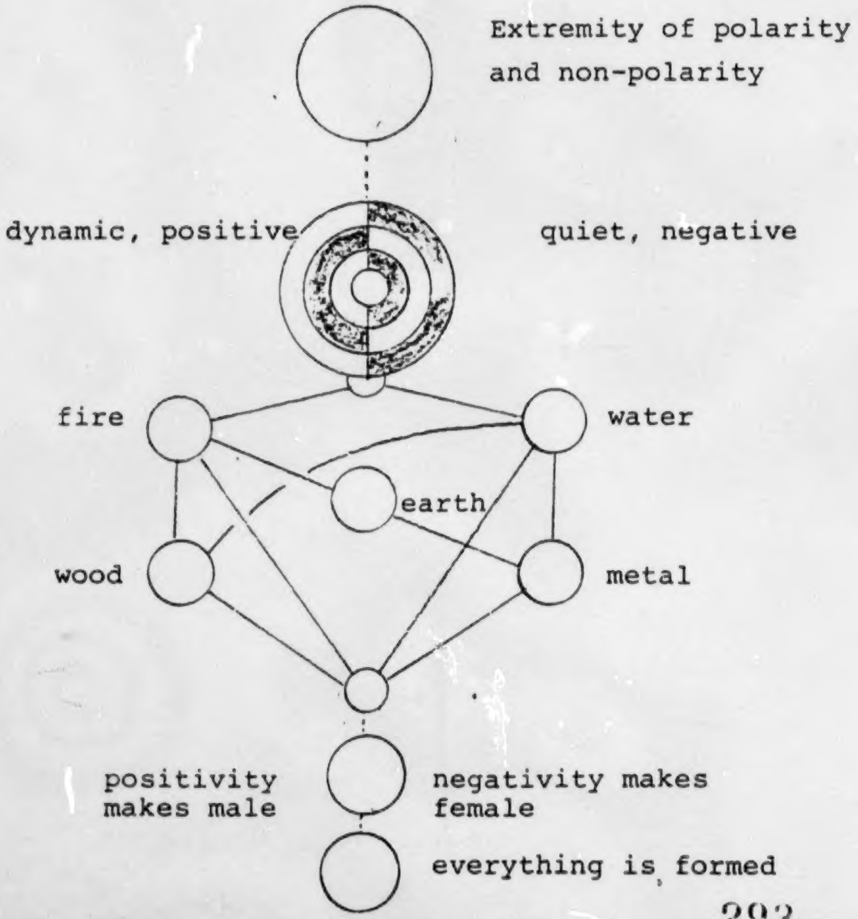

Extremity of polarity and non-polarity
dynamic, positive
quiet, negative
fire
water
earth
wood
metal
positivity makes male
negativity makes female
everything is formed

Fig 1 + 2

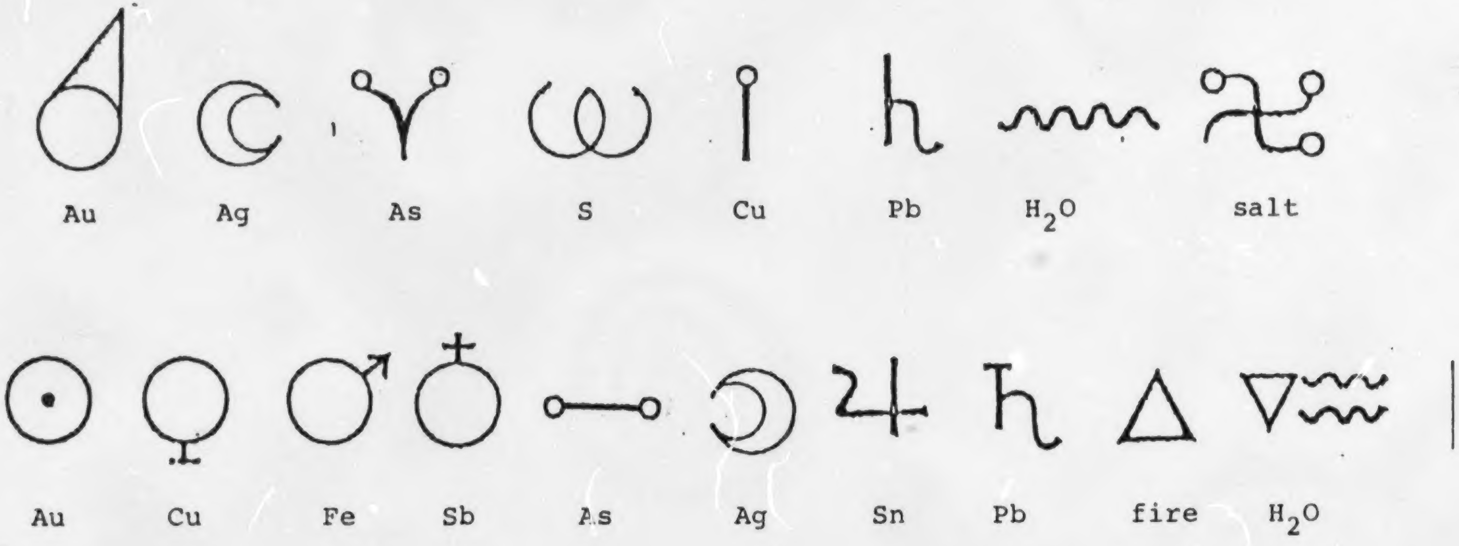
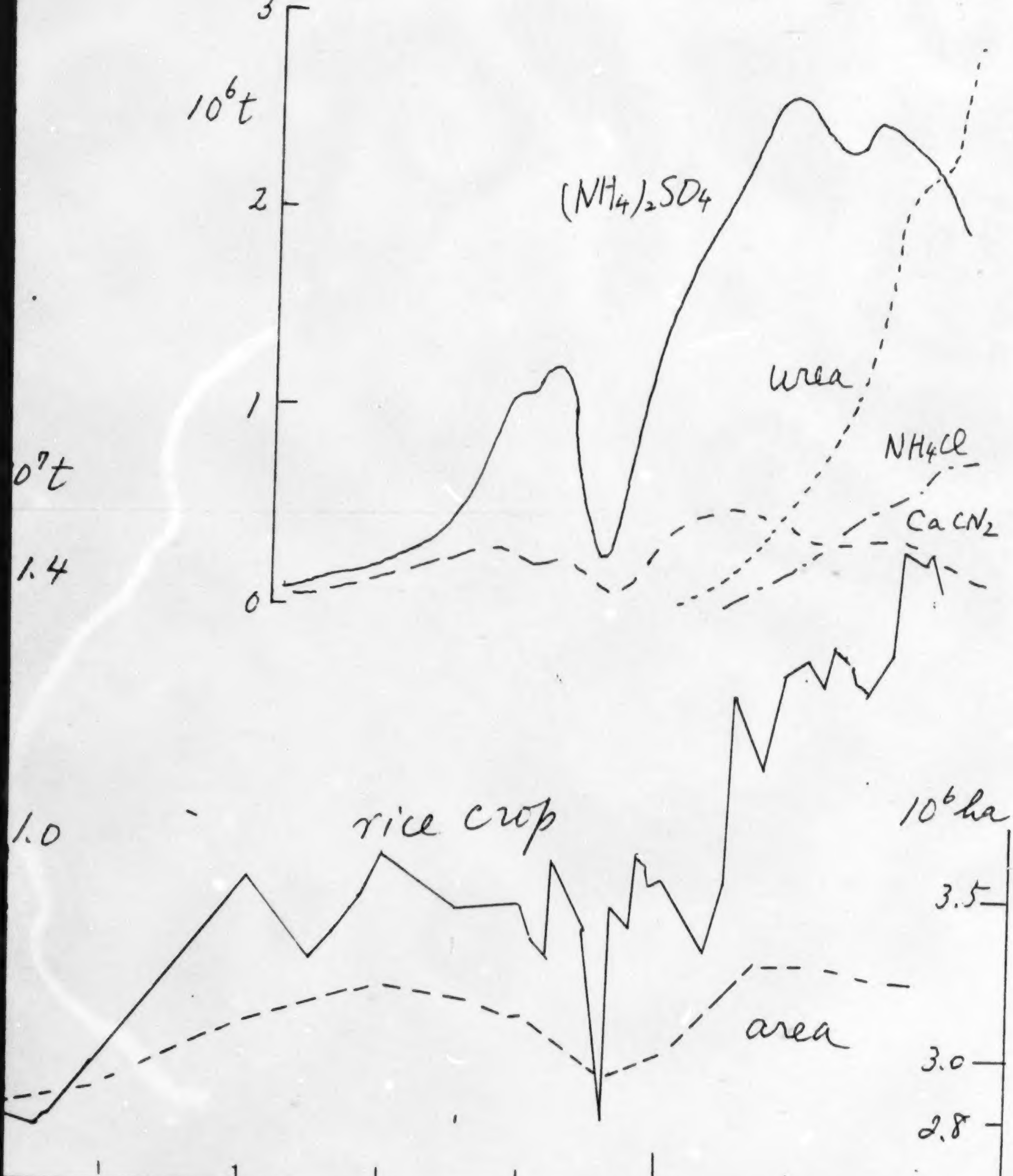

Au
Ag
As
S
Cu
Pb
H_2O
salt
Au
Cu
Fe
Sb
As
Ag
Sn
Pb
fire
H_2O

Fig 3

FIG 5


3
$10^6 t$
2
1
0
$(NH_4)_2SO_4$
urea
NH_4Cl
$CaCN_2$
0^7t
1.4
1.0
rice crop
10^6 ha
3.5
3.0
2.8
area
0
1950

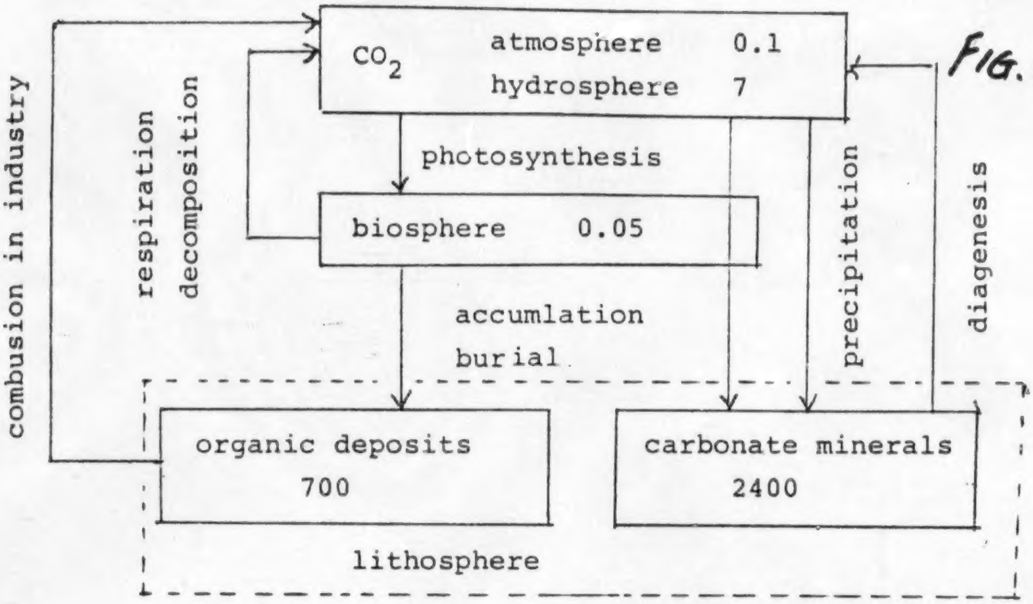

CO$_2$
atmosphere 0.1
hydrosphere 7
photosynthesis
biosphere 0.05
accumlation
burial
organic deposits
700
carbonate minerals
2400
lithosphere
combustion in industry
respiration
decomposition
precipitation
diagenesis

FIG. 6

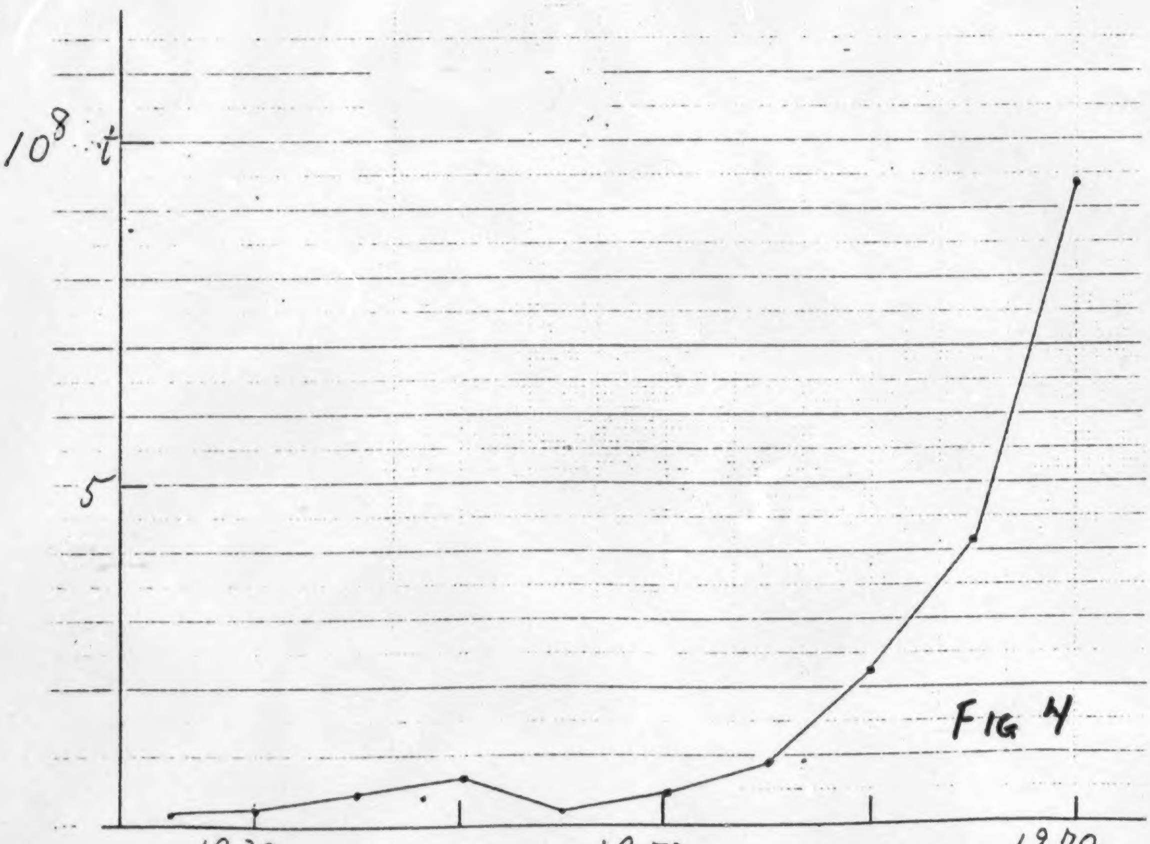

10^8 t
5
1930
1950
1970

FIG 4

Position Paper

What are the best ways of using "case studies" of environmental impact related to the chemical kingdom as teaching tools?

William F. Kieffer, College of Wooster

Brasted: Who are you kidding with that "chemical kingdom" stuff? The way things have been going in recent years it's the "environmental kingdom" that we have to invade to get the students' attention! I am not sure that formally constructed *case studies* are better than an extensive and continuous stream of illustrations of application of chemical concepts to the solution of environmental problems. The latter can be almost incessant throughout any course. I shall refer to "case studies" in this expanded sense.

I have used two almost opposite approaches to this idea of getting the students to appreciate the relevance of chemistry to their concerns about the environment. One is to use an essentially chemistry text and use the environmental problems to illustrate the chemistry as it is developed by the text. The alternate approach is to use a text that is focused on ecology or the environment, and then to bring in via lecture material the important fundamental chemical concepts that are involved in dealing with environmental problems. I believe I have been more successful with the latter approach.

I have built a course using Wade's "Contemporary Chemistry" (Macmillan 1976). The contents belie the title; there is really very little honest-to-God chemistry in the book. But it does a great job of giving accurate and balanced treatment to much pertinent information about current environmental problems. Two things need to be done. First, I spend almost no time going over the text material, but lecture almost entirely on the chemistry behind text statements. For example, I take at least two periods on the text sentence, "...a total calorie picture is misleading because ... an adequate diet must include protein; ... a balance of the 20 or more amino acids is required for living cells." Students end up learning the essential ideas of carbohydrate and protein structure, synthesis, and digestion, even the singlehandedness of all terrestrial living protein constituents. The second thing that needs to be done is to bring the information up to date by reference to current periodicals or scientific literature reports. No text can ever be really up to date!

I think the important feature in using any kind of case history is to be sure that the students who start out knowing little chemistry are able to learn some. I want my course to a *chemistry* course, not merely an ecology course dedicated to worship of the current gods of the movement (Ehrlich, Commoner, Nader et al.).

One technique I have used with some success is to assign case history studies to individual students or occasionally small teams of students. The assignment is made about the second week of the term, after the students have some overview of the term's topics and coverage. Students make choices from a list of topics. They are expected to look ahead at the text material, search the current periodical literature, refer to pertinent government or environmental organizations' reports and to build a rather full outline or "pre-first draft" of their term paper. This pre-first draft is due at about the 2/3 point in the term. My review of this document with the students usually focuses on the chemistry they need to understand to interpret properly the facts they have gathered. Then, armed with references to textual treatment of the chemistry (e.g., a section on "osmosis" for the student reporting on "Desalination of Sea Water") and some more pertinent references to articles on the theme (e.g., from Science which has no subject index), the student is expected to modify and expand the pre-first draft into the final paper. If the class is small enough - or can be sectioned, a good procedure is to have students make an oral presentation to the group near the end of the term. This timing has the advantage of better preparation for the material by all class members, so discussion can be even lively at times.

Another procedure that is great for producing student response or discussion is to have the luck to find an article in the "popular" literature (Sunday Supplement Magazines are a likely source) that is badly biased or based on misinformation. The assignment for this kind of case study is to correct the reporter's mistakes. Arguments about the Delaney Clause or the idea of zero tolerance levels are prime examples. No better way exists for giving students interest in, and best of all confident in the application of what fundamental science they have learned.

So, in summary, I believe that case history material from the "environmental kingdom" is an important part of the course for non-science students. However, the crucial feature about using this material is that it be used to introduce real science, the chemical concepts upon which solutions to environmental problems must be based.

Position Paper

Using Everyday Encounters with Chemistry as Teaching Tools

Instruction in Chemistry for the Non-Major Student

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The point was made earlier that one of the things we must do effectively in the future is to get students to appreciate just how much the principles of chemistry are involved in their everyday lives. What we know and what a great majority of students do not is that everything they feel, see and sense, and most of what they are involves chemistry in one form or another. Furthermore, our understanding of this chemistry is very far advanced. Although it might be possible to design a chemistry course that begins with the material world and uses chemistry to explain why things are as they are, it is both more simpler and more in line with our traditions to teach the principles of chemistry and then to use everyday examples to illustrate them. All of us do this to varying degrees, and occasionally we can help one another by sharing our favorite or most unusual applications. Here are a dozen common examples, offered simply to stimulate discussion:

1. Properties related to structure. These are relationships that often can be made more meaningful by questions such as: how does bonding enable us to understand why a silver spoon placed in ice cream gets cold much more rapidly than a ceramic spoon placed there? Why does salt dissolve in water but your teeth do not, even though salt and the chief component of teeth are both ionic compounds? Why is wood harder than polyethylene but softer than diamond? Why does graphite work in pencils and as a lubricant? Why is sand harder than skin even though they are both string-like coiled molecules?

2. Energy levels in atoms. The idea of electronic transitions and energy level spacing can be dramatically illustrated by getting the students to understand how they see color in non-luminous objects like their sweaters and shirts. The energy level spacing in the dyes is of course responsible for the color of light absorbed. The observer sees the complement of the color absorbed. Thus a bright red sweater should be absorbing in the green end of the spectrum, a bright blue shirt would be absorbing on the red end. The students can verify this complementary relationship by observing the absorption spectrum of a complex ion using a spectrophotometer.

3. Acid Base Balance in Body Chemistry. Some interesting but simple principles of acid-base chemistry can be illustrated by the chemistry of carbon dioxide in the blood and also of that of $H_2PO_4^-$, $H_2PO_4^{2-}$ ions at the kidneys. The cells must rid themselves

of substantial quantities of carbon dioxide - more than is soluble in the blood. The carbon dioxide reacts with water in blood to form carbonic acid, but if this were allowed to build up, the blood pH would drop and acidosis would result. To prevent this, the carbonic acid is decomposed at the lungs and carbon dioxide is expelled. Expelling too much carbon dioxide at the lungs will raise the pH, expelling too little carbon dioxide at the lungs will lower the pH. Thus we have a hyper- and hypoventilation. Should a condition of abnormal blood pH persist the kidneys will neutralize excess acid using HPO_4^{2-} or neutralize excess base by using $H_2PO_4^{1-}$.

4. Shapes of Molecules. The importance and consequences of shapes of molecules can be illustrated by taste, odor and drug action. All of these are related to specific receptors on the tongue, in the nose or at parts inside the body. Sweetness, for example, requires an OH separated by about 3 angstroms from a highly electronegative atom. If, in addition to these features, a molecule has the ability to alter the conformation of the receptor protein the sweet taste will be intensified.

5. Properties of real gases can be emphasized by observing the pumping of air into a tire or releasing air from a tire or by describing the way refrigerators work. This can be extended to show how this principle can be used to manufacturer an air conditioner and heater both contained in the same container, or even some aspects of solar heating.

6. Properties of surfaces can be reinforced by showing why towels absorb water and raincoats do not. How the meniscus in a clean glass differs from one in a glass that has grease on its walls; why water spilled on a waxed floor beads up, how waxed floors make cleaning easier; and how soaps and detergents work.

7. Properties of simple ions can be illustrated by raising and answering such questions as: how is magnesium ion's high hydration energy related to the advertisement "Phillips is a true blue friend". It also might be illustrated by explaining how a flow of calcium ions, in response to a nerve signal results in muscle contraction, and how withdrawal of the calcium ions results in muscle relaxation. This occurs in all of our muscles including the heart. Examples such as these also serve to emphasize the independent character of simple ions, a feature many beginning students seem to have difficultly grasping.

8. Coordination chemistry has so many applications it is hardly necessary to mention more. One that is not perhaps well known is the coordinating ability of zinc ions. This is primarily responsible for the role of Zn^{2+} in wound healing, in vision, in the conversion of carbon dioxide to carbonic acid at the blood cell interface, and the reverse of this reaction at the lungs.

9. Certain principles of electrochemistry can be illustrated by the manner in which an electrical potential is created by differing concentrations of sodium and potassium ions on the outside and inside of the nerve cell. This voltage makes it possible for the nerve signal to be transmitted along the cell. The interesting part is that energy must be provided at every point along the nerve cell for the potential to be large enough to transmit the signal. This is the reason nerve cells require so much more energy than other cells.

10. Some important aspects of chemical reactions can be illustrated by the role of oxygen in body chemistry. Questions such as: why must the body receive a constant supply of oxygen, but it does not have to take food as often? What are the chief reactions of oxygen inside the body? Why is the brain so much more dependent on oxygen than other body organs? For example, why does the brain with only about 2% of the body's mass use approximately 20% of the body's oxygen when the body is a rest? All of these are important questions that have answers based on chemical principles.

11. Energy. To illustrate various aspects of energy and the fact that many chemicals are energy reservoirs, it might be helpful to point out and explain why two weeks of sunshine on a square meter of the earth's surface is equivalent to one gallon of gasoline, 14 pounds of coal, 26 pounds of straw, 30 pounds of bread, 96 pints of milk, 38 pounds of steak, 300 pints of beer and 24 barrels of whiskey.

12. To try to get the students to think more effectively about relatively large and relatively small amounts of materials two approaches have been successful. The first is to indicate that the normally prescribed dosages of drugs usually are compared on a pro-weight basis because of the varying sizes of individuals. In everyday units they might be expressed as ounces of drug per pound of body weight. In scientific units this becomes milligrams of drug per kilogram of body weight which is identical to parts per million. The prescribed dosage of a mild sedative such as amytal (a barbiturate) is normally between three tenths and seven tenths milligram per kilogram four times daily. The normal dose for morphine might be 0.1 mg/kg or for a normal 150 pound person, 6.82 mg/day, the equivalent in weight to 0.007 milliliters of water.

Another way to get students to think about relatively large and small numbers is in terms of the elemental composition of the human body. The elements oxygen, carbon, hydrogen and calcium are present in amounts that vary between 10,000 and 630,000 parts per million; sulfur, phosphorus, sodium, potassium, chlorine and magnesium are present in amounts between 400 and 700 parts per million; iron, silicon and zinc are present in amounts between 25 and 50 parts per million; rubidium, copper, strontium, bromine, manganese and iodine are present between one and ten parts per million; aluminum, lead, barium, molybdenum, boron are present between two and five parts per ten million; arsenic, cobalt, chromium, lithium, vandadium and nickel are present in amounts between of two and four parts per hundred million, and cadmium and selenium are present in even smaller amounts than these.